Contents #105

Contributions on any matter of interest to second-level chemistry teachers are welcome. Normally the results of research (chemical or educational) are **not** published, except in a general form or as a review. Articles should be submitted electronically (email or disc) to **peter.childs@ul.ie** together with a printed copy.

For subscription details etc. see inside back cover.
Cover design: David Lilburn, University of Limerick
Cover photo: The new Analog Devices building at the University of Limerick (Photo: UL)
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Editorial #105

How not to do curriculum reform

What is the best way to do curriculum reform in science? There are lots of lessons to be learnt from the way curriculum reform has been done in the past, not just in Ireland but also in other countries. Here are some of the things not to do:

- Don't listen to teacher's comments on existing syllabi and where they aren't working.
- Have a consultation but don't listen or take account of the majority view.
- Don't think about assessment in relation to the outcomes and content of the new curriculum but leave it to the end.
- Revise the curriculum starting with the highest level (top-down approach) and working down.
- Don't take proper account of the transition from one level to another (primary → junior secondary → senior secondary) in content, assessment, pedagogy, learning style.
- Don't pilot new ideas or content or methods and when there is a pilot study, don't wait for it to be fully evaluated before implementation.
- Don't take account of what has been learnt from science education research over the past 30-40 years.
- Have a curriculum/syllabus committee determined by political balance rather than expertise.
- Don't provide enough and appropriate CPD to equip teachers to teach the new curriculum.
- Don't provide the additional resources to teach the new curriculum in the way it was intended.
- Don't listen to the views of and criticisms by science teachers on the draft curriculum.
- Rush into the curriculum implementation to meet political rather than educational objectives.
- Don't issue sample exam papers until the last year of the course.
- When the whole process is finished and has started to be implemented, produce a STEM report on what should be done.

Do these points ring any bells? Some or all of these have characterised science curriculum development at second level in Ireland over the past 30 years. At the moment we are about to introduced a new junior cycle science curriculum (subject to union approval of the latest junior cycle proposals). The revised LC science subjects were 'finalised' some time ago (although they are far from being in a suitable form) **prior** to the junior cycle science being finalised. The ISTA still has major reservations about the new science courses and the whole question of assessing the practical component is still up in the air. We are still awaiting publication of the STEM Review Group report (due in 2014) which will look at all aspects of STEM provision in schools.

Peter E. Childs
Hon. Editor

Sometimes I am a little unkind to all my many friends in education ... by saying that from the time it learns to talk every child makes a dreadful nuisance of itself by asking "Why?." To stop this nuisance society has invented a marvellous system called education which, for the majority of people, brings to an end their desire to ask that question. The few failures of this system are known as scientists.
Sir Hermann Bondi
'The Making of a Scientist', *Journal of the Royal Society of Arts*, June 1983, 403

Education News and Views

The Editor welcomes contributions and news of interest to chemistry/science teachers in this section.

Junior cert reform proposals

In May the Minister of Education, Jan O'Sullivan put revised proposals for junior cycle reform to the second level teachers unions. An agreed document resulted after the talks and can be found at https://www.education.ie/en/Publications/Education-Reports/Junior-Cycle-Reform-Joint-Statement-on-Principles-and-Implementation.pdf

The two unions (ASTI and TUI) accepted them subject to a vote by science teachers in the Autumn.

The Minister outlined 5 principles:

*the need to recognise a wide range of learning;

*a requirement to considerably reduce the focus on one terminal exam as a means of assessing our students;

*necessity to give prominence and importance to classroom based assessment;

*greater professional collaboration between teachers to be a feature of our schools;

*both parents and students to get a broader picture of each student's learning throughout the whole of junior cycle.

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New Junior Science course

The new Science course will be introduced in September 2016. The Junior Cycle Science Development Group will focus on the development of the *Assessment Specification for Junior Cycle Science.* This document will provide material on assessment for reporting, setting out details of the practical arrangements related to the school work components.

Furthermore, the Development Group has identified specific learning outcomes on which to focus as we develop more annotated examples of student work. Both the assessment specification and additional annotated examples of student work will be made available on curriculumonline.ie in Autumn 2015.

In response to concerns raised during the consultation on the draft specifications, we are currently examining how best to support teachers with the task of unpacking learning outcomes as they plan for teaching, learning and assessment.

For the latest updates consult:
http://juniorcycle.ie/Curriculum/Subjects/Science/Science

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ChemEd-Ireland returns to UCC

Declan Kennedy and his team will be organising this year's ChemEd-Ireland one day conference for chemistry teachers on Saturday October 17th. More details later or contact: d.kennedy@ucc.ie

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No sign yet of STEM report

The long-awaited report of the STEM Review Group has still not been published in late July. It was due last summer and has been with the Minister of Education for some time. The purpose of such reports is to inform policy and the longer it is delayed, valuable time is being lost. We hope to give the summary when it is published but I wonder what it will add to the Task Force Report of 2002, most of whose recommendations were never acted upon. Acting reports is one thing; acting on them is another.

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Changes in Chemistry in Action!

After many years sending out *Chemistry in Action!* at the special publications rate, we have been told by An Post that we are no longer eligible. (This explains the insufficient postage stickers on the last issue.) The full postage rate is €1.60 versus 95c, so this is a big increase in costs. To adjust for this we have decided to print only two issues a year (Summer and Winter), but to make them larger, so that the number of pages per year will not be too different. This will start with this issue. Ideally these will be produced in the middle and at the end of the year.

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Science Education moves

Miriam Doran Hamilton was heading up the PDTS Junior Cycle Science team but has moved to Mary Immaculate College, Limerick, together with Anne O'Dwyer (formerly with EPI-STEM in UL), where both have been appointed as lecturers in science education. They will be responsible for teaching science and science education to intending primary teachers.

Michael Seery from DIT, one of the organisers of last year's ChemEd-Ireland conference, is moving to the University of Edinburgh as Reader in Chemical Education within the Department of Chemistry. This will be a loss to Ireland but it is great to see the value of chemical education being recognised within chemistry, which is its natural home.

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Proceedings of ECRICE 2014

The 12th European Conference on Research in Chemistry Education (ECRICE 2014) took place in Jyväskylä, Finland from 7th of July to 10th of July, 2014. The international biennial conference was hosted by the Department of Chemistry, University of Jyväskylä, and organized under the auspices of EuCheMS Division of Chemistry Education and the Division of Chemistry Education of the Finnish Chemical Society. Altogether 145 participants from 31 different countries took part in the conference at the shores of Lake Jyväsjärvi, in Agora on the Mattilanniemi Campus of Jyväskylä University.

The Proceedings of the conference have now been published in two parts in the *LUMAT* electronic journal, in the July and August issues.

The Proceedings issues can be accessed free-of-charge at:

http://www.luma.fi/lumat-en/3863

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Future Conferences

ISTA conference in Limerick

The ISTA Conference will be held in Limerick Institute of Technology, 8-10 April 2016. The chair of the organising committee is Maria Sheehan and a full programme of lectures and workshops has been arranged.

www.ista.ie

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Primary science conference in Belfast

From 9-11 June 2016 the Primary Science Teaching Trust will be holding an international conference in the Waterfront Hall, Belfast. The theme will be 'No boundaries, no barriers'.

www.primaryscienceconference.org

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ICCE 2016 in Malaysia

The next International Conference on Chemical Education (ICCE) will be held in Kuching, Malyaisa from 15-20 August 2016.

www.icce.2016.org.mv

The previous ICCE was in Toronto in 2014 and the one after Malaysia will be in Sydney in 2018.

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ICASE 5th World Conference

ICASE is the International Council linking science teaching associations and the ISTA is a member. The 5th World Conference on Science and Technology Teaching will be held in Antalya, Turkey from 1-5 Nov. 2016.

www.icase2016.org

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ECRICE 2016

The European Conference on Research in Chemical Education will be held in Barcelona, Spain from 7-10 Sept. 2016. This is organised under the auspices of the EuCheMS Division of Chemical Education.

http://ecrice2016.com/

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ESERA comes to Dublin

The 2015 ESERA conference was held in Helsinki, Finland from 30th August to 4th September. This is Europe's largest science education conference and was attended by over 1,300 people. At the conference it was confirmed that Dublin would be the venue for the 2017 conference. It is being jointly hosted by CasteL, DCU and EPI-STEM, UL and will be hosted on the DCU campus. Eilish McLoughlin is the chair of the organising committee. The dates are 21-25 August 2017. ESERA covers all levels of education and all subjects, as well as the theory of of science education.

www.esera2017.org

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Proceedings: ChemEd-Ireland 2014

"Chemistry in Context" Dublin Institute of Technology

The School of Chemical and Pharmaceutical Sciences in Dublin Institute of Technology (DIT) were delighted to host the 33rd Chem-Ed Ireland conference for chemistry teachers on Saturday October 11th 2014 from 9.30am to 4pm at the DIT Kevin St campus. Over 70 teachers travelled from across the country to participate and the theme for the day was Chemistry in Context. As usual, there were opportunities to share resources and ideas relevant to teaching chemistry and science in Ireland and the programme included both presentations and workshops.

Engaging and informative workshops were run on Chemical analysis in context, Making models to teach covalent bonding, Making stop-motion animations and Engaging and effective lab demonstrations for analytical chemistry. Presentations addressed a wide range of topics including Flipping the classroom, Applications of chemistry research to the treatment of addiction, Teaching enquiry with mysteries, the Junior Cycle for Teachers Team, SciFest science fairs, and Chemistry teaching resources from the Royal Society of Chemistry, Chemistry is All Around Us project, Amgen workshops and the Scientix portal.

The guest speakers were Dr Kristy Turner, Royal Society of Chemistry School Teacher Fellow and Teacher Trainer and Dr Mike Southern, Trinity College Dublin, course director (Medicinal Chemistry) and medicinal chemistry research group leader.

Further information on the event is available at the conference website: http://www.dit.ie/chemistry/chemed2014/ The programme is shown below. A Storify compilation of tweets from the conference can be viewed at: https://storify.com/clairemcdonndit/chemed-ireland-2014

The 34th annual ChemEd Ireland Conference will take place in UCC on Saturday 17th October 2015.

Dublin Institute of Technology
ChemEd Ireland 11th October 2014 – SCHEDULE

Time	Speaker / Workshop Facilitator	Activity
9.30-9.55		Registration
9.55-10.00		Welcome
10.00-10.30	Miriam Doran Hamilton, Junior Cycle for Teachers Team	An Introduction to the Junior Cycle for Teachers Team and Continuing Professional Development provision
10.30-10.45	Angela McKeown and Stephanie Nelson, RSC	Royal Society of Chemistry resources for teachers
10.45-11.00	Peter Childs, NCE-MSTL, University of Limerick	Teaching Enquiry with Mysteries Incorporated
11.00-11.30		Tea / Coffee and Exhibits
11.30-11.45	Kristy Turner, RSC Teacher Fellow & Teacher Trainer, *RSC Ed. Div. Invited Speaker*	F****ing classrooms: inverting the traditional learning cycle with 14-16 year old chemistry students.
11.45-12.00	Marie Walsh, Limerick IT, and Diane Condon	Chemistry is All Around Us - 3 years of resource gathering
12.00-1.00	John Cassidy & Vanessa Murphy, DIT	WS1: Analysis in Action (UV, IR, MS, GC & HPLC analysis in context)
	Iris Suitor, Royal Society of Chemistry	WS2:LearnChemistry CPD-Developing Expertise in Analytical Techniques
	Kristy Turner, *RSC Ed. Div. Invited Facilitator*	WS3: Crafty covalent bonding
	Maria Sheehan, Professional Development Service for Teachers	WS4: Making and using stop-motion animations to help in the teaching and learning of Chemistry
1.00-2.00		Lunch and Exhibits
2.00-3.00	John Cassidy & Cora O'Donnell, DIT	WS1: Analysis in Action (UV, IR, MS, GC & HPLC analysis in context)
	Iris Suitor, Royal Society of Chemistry	WS2:LearnChemistry CPD-Developing Expertise in Analytical Techniques
	Kristy Turner, *RSC Ed. Div. Invited Facilitator*	WS3: Crafty covalent bonding
	Maria Sheehan, Professional Development Service for Teachers	WS4: Making and using stop-motion animations to help in the teaching and learning of Chemistry
3.00-3.30	Mike Southern, School of Chemistry, Trinity College Dublin, *RSC Ed. Div. Invited Speaker*	Chemistry and Addiction - Organic Chemistry in Context
3.30-3.45	Maria Sheehan & Mary Mullaghy	Amgen workshops and Scientix portal
3.45-3.55	Sheila Porter, CEO, SciFest Ltd.	SciFest Science Fairs in Schools and Colleges
3.55-4.00	Draw for molecular model kit and other spot prizes (donated by Timstar, Lennox Educational & Anyone4Science) Evaluation feedback sheets circulated and close of conference	

Photo montage: ChemEd-Ireland 2014 in Dublin Institute of Technology (Kevin St) (Photos: DIT)

Models of bonding workshop

Dr Vanessa Murphy (DIT) discussing applications of HPLC & GC during the Analysis in Action workshop

Dr Kristy Turner giving the RSC keynote on Flipping the Chemistry Classroom

Extracting pigments from spinach during the Royal Society of Chemistry workshop with Iris Suitor on Developing Expertise in Analytical Techniques

Workshop on Making and Using Stop-motion Animations to Help in the Teaching and Learning of Chemistry

RSC Resources for teachers

Stephanie Nelson (RSC)
RSC Education Coordinator, Queen's University, Belfast, Northern Ireland
s.nelson@qub.ac.uk.

The Royal Society of Chemistry is the leading organisation in Europe for advancing chemical sciences and is supported by a network of 45,000 members worldwide.

The education team are constantly developing resources and tools for Chemistry teachers, and these are available through the award winning Learn Chemistry website. Although a daunting 3947(!) resources are available (at http://www.rsc.org/learn-chemistry) there are very useful filters which can be applied to ensure that you find what you're looking for in the shortest possible time.

A recent development is the **Learn Chemistry Partnership**. This initiative is an effort to gain an email contact address in every school, so that interested teachers are kept informed about opportunities and events in their region. We are looking for one teacher in each school to agree to be the email contact and in return, they will get free RSC membership. You can find out more about LCP at http://www.rsc.org/membership-and-community/supporting-organisations/.

Many teachers will already be aware of the excellent resource provided by the magazine Education in Chemistry. This is now available as an app on iOS, Android and in a web-reader version. All issues of the magazine are free to download throughout 2015. In addition to bimonthly issues, app readers will also have access to themed supplements on emerging topics in chemical education.

In Ireland, this year's big event has been the extension of the Spectroscopy in a Suitcase programme with kits now available to schools through partnerships with University College Cork, Cork Institute of Technology, Trinity College Dublin, University College Dublin and Queens' University Belfast. This scheme is run as an outreach activity which gives school students the chance to learn about spectroscopy through hands-on experience. As well as covering the principles of spectroscopic techniques, the activities use real-life contexts to demonstrate the applications of the techniques

The kits are hosted by Universities and events are delivered by University students, so there is a strong emphasis on encouraging school pupils to consider studying chemistry and the career opportunities available. To book a visit for your school, or just find out more, visit the Spectra School:
(http://www.rsc.org/learn-chemistry/collections/spectroscopy/spectroscopy-in-a-suitcase).

If you feel there is anything more you would like to know about the RSC's education resources, or if you'd like to run a chemistry careers event or a 'Chemistry at Work' workshop please contact your education coordinator Stephanie Nelson at s.nelson@qub.ac.uk. We will no doubt see you at Chem-Ed Ireland again this year, for another infusion of enthusiasm!

N.B. An Education Coordinator based in the Republic is about to appointed and will be based in the Department of Chemistry, Trinity College, Dublin.

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TEMI: Teaching Enquiry with Mysteries Incorporated

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Introduction

Harnessing the emotional power of magic, myth and mystery is one of the latest trends in science education. TEMI, the EU-funded FP7 Science in Society project is attempting to promote enquiry-based teaching in schools to help young students across Europe develop a passion for science. The aim of this 3 ½ year teacher development project is to help transform science and mathematics teaching practice across Europe by giving teachers new skills to engage with their students, exciting new resources and the extended support needed to introduce effectively enquiry-based learning into their classrooms. Innovative 'TEMI Enquiry Labs' and workshops are being developed among teacher training institutions and teacher networks across Europe, which will be based around core scientific concepts and using the emotionally engaging activity of solving mysteries, i.e. exploring the unknown. It is intended to train 6 cohorts of 10-12 in-service teachers over the course of the project, in each country, in a series of two one-day workshops. A spoke-and-hub model for coordination and delivery allows the project to both respond to local country needs and to maintain an overall EU wide sharing of best practices. The coordinator of this project is Professor Peter Mcowan of Queen Mary College, University of London, acting as the hub, while the spokes comprise of 13 partners from 11 countries (see Table 1), 9 of whom (in bold) are involved in producing science teachers.

TEMI Partners
Queen Mary, University of London - UK
Università degli Studi di Milano - Italy
Bremen University - Germany
University of Limerick - Ireland
Sheffield Hallam University - UK
Hogskolen I Vestfold - Norway
University of Vienna – Austria
Weizmann Institute - Israel
Leiden University - Netherlands
Charles University Prague - Czech Republic
Sterrenlab - Netherlands
TRACES – France
Cnotinfor - Portugal

Table 1. Consortium of the TEMI project

Engaging the disengaged: the TEMI approach

The TEMI project is based on the well-known 5E model of enquiry [1], as shown in Figure 1.

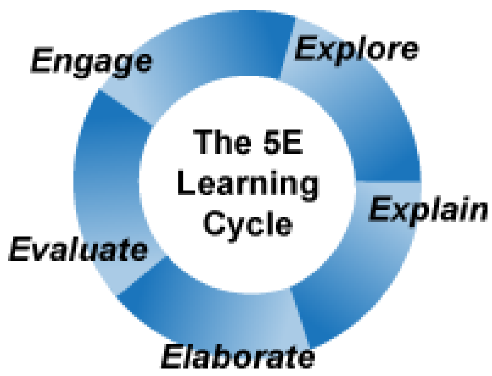

Figure 1. The 5E model for enquiry (http://ergopedia.com/ergoweb/home_chemistry.php)

In this model the lesson proceeds through a number of stages (Table 2), of which the first one is Engagement. The particular focus of the TEMI project is on this stage of the lesson. Unless students are engaged and motivated, and have their curiosity aroused so that they start asking questions: “Why? How? What if?”, then there will be no real enquiry. The idea behind TEMI is to use mysteries, or unusual or discrepant events, to capture the students’ interest and lead them into the 5E process.

Table 2.The stages of the 5E model [1]

Engagement	Students’ prior knowledge accessed and interest engaged in the phenomenon
Exploration	Students participate in an activity that facilitates conceptual change
Explanation	Students generate an explanation of the phenomenon
Elaboration	Students' understanding of the phenomenon challenged and deepened through new experiences
Evaluation	Students assess their understanding of the phenomenon

a) What is a mystery?

In science education, a mystery is a phenomenon or event that provokes the perception of suspense and wonder in the learner, in order to initiate an emotionally-laden “want to know”-feeling, which leads to an increase in curiosity and which initiates the posing of questions by the students, to be answered by enquiry and problem-solving activities [2]. Such mysteries, which have a scientific basis and explanation, are also known in the literature as discrepant events. There is a massive literature describing discrepant events and their role in science education [3][4].

A mystery is a good mystery for a classroom enquiry if:

- it can be investigated and explained scientifically and is within the competency of the students involved,
- it provides affective engagement for the students,
- it generates curiosity and leads to student questions,
- it ‘problematises’ or makes knowledge and enquiry skills part of the answer to the mystery,
- it covers a sufficient part of the nationally assessed curriculum to justify time spent,
- it is simple enough to be a ‘discrepant event’, and generate cognitive conflict,
- the time between mystery and answer is limited (1-2 lessons),
- it is introduced by a pedagogy that relies on the mystery itself.

· *A mystery is a bad mystery for a classroom enquiry if:*

- it provides engagement for the teacher only, but the students are not excited,
- it generates little curiosity and the teacher has to do all the work,
- it is answered by science concepts that are too difficult for students to grasp,
- it is peripheral or unrelated to the subject content of the curriculum,
- it is too complex, so that students explain it away as ‘magic’ (a trick that I don’t need to explain).

The various partners are tasked with developing lessons around such scientific mysteries, introducing them to practising science teachers, who will try them out in schools and evaluate their effectiveness in engaging their students. The Irish programme is described in the next section. In the ChemEd-Ireland talk, Peter Childs used the blue bottle demonstration as an illustration of the approach. The blue bottle is a stoppered flask, which is initially colourless, but when shaken turns blue and then slowly decolorises. The process can be repeated many times. This is the starting poitn for asking questions and proposing possible asnwers, which can be tested experimentally. The initial demonstration is the Engagement phase, and this then leads on to the Explore phase and so on.

(For information on how to do and use the blue bottle demonstration, see: http://www.rsc.org/learn-chemistry/resource/res00000729/the-blue-bottle-experiment and for a video and a variation on the blue bottle see Irwin Talesnick https://www.youtube.com/watch?v=mxuJ8IOHAlk)

Experience in Ireland

a) Working with pre-service science teachers (PSSTs) to develop materials

The TEMI team in the University of Limerick worked since the summer of 2013 with 4 pre-service science teachers, who were in their final year of study. Three of these students, as part of their Final Year Project (FYP), have developed a set of classroom teaching materials in the form of TEMI lesson plans and activity sheets in the areas of chemistry, physics and biology respectively (for both the Junior Cycle – general science, and the Senior Cycle – single subject science). The fourth pre-service science teacher, however, has developed an 8 week science module for Transition Year science students, *Scientific Mysteries*, which includes physics, chemistry and biology units. (Transition Year in Ireland is an optional year between Junior and Senior Cycles, which is intended to broaden the students' educational experience by providing a bridge to *"help pupils make the transition from a highly-structured environment to one where they will take greater responsibility for their own learning and decision making"* [5]).

All of the developed TEMI classroom material has been trialled by pre-service science teachers from the University of Limerick, while completing their final teaching practice placement in the Autumn of 2013. Some of the material has also been piloted by a number of in-service science teachers in advance of the first workshop. This material will be revised, based on feedback from the teachers and FYP students, and will be used as bank of resources for all participants involved in the TEMI project.

(In 2014 the team worked with a further 5 PSSTs to develop more TEMI style lessons using mysteries to engage students.)

b) Teacher recruitment strategies employed

The participants for cohort 1 include the 4 pre-service science teachers (mentioned above) and 5 in-service science teachers from 5 second-level schools in Ireland. The in-service science teachers were recruited in the following ways:

1. The TEMI project was publicised through an insert in issue #99 of the journal *Chemistry in Action!* and also in *SCIENCE*, the official journal of the Irish Science Teachers' Association (ISTA). This informed a large number of science teachers and allowed those who were interested in participating in the project to contact the UL TEMI team.
2. Science teachers, known to the team members to be enthusiastic and willing to try new ideas, were invited to join the project, subject to the support of their school.
3. Short taster TEMI workshops were run at science teachers' conferences to recruit new participants. (For example, a talk was given at ChemEd-Ireland 2014, at the Amgen Scientix Workshops in 2014 and at the 2015 ISTA conference).
4. Teachers were also recruited when team members visited schools to supervise teaching practice students and when running science magic shows.

For interested participants, an invitation letter, consent form and information sheet describing the TEMI project and the requirements involved in participation were then sent to school principals, who were asked to nominate a teacher for cohort 1and one for the subsequent cohort 2. Each of the participating schools (teachers and principals) completed and signed an agreed Commitment of Participation in the TEMI project. This detailed the necessary involvement of the Science teacher in the TEMI project.

c) TEMI workshop design

The quality framework that will be used for the workshops in UL has been developed by the working team in Sheffield Hallam University in London, and has been developed as a result of piloting a two-day workshop-based programme with secondary school science teachers in the UK. There will be a specific focus on the "transformative power of practice" [6] in the workshops, where participants will be strongly encouraged to become actively involved in the workshop, in order to maximise the chance that they will know how to implement enquiry when they return to their classrooms.

By participating in the workshops teachers will:

- become familiar with the 5E model of enquiry,
- evaluate the newly developed curriculum materials,
- learn to use mysteries to engage students in structuring their ideas,
- develop their role as an expert in working scientifically (not as a dispenser of knowledge),
- practise generating their own TEMI-style lessons in a collaborative exercise,
- reflect with peers, scientific researchers and curriculum developers.

The timetable for Day 1 of the first workshop is shown in Table 3 below.

Table 3. Timetable for Day 1 of the first teacher training workshop

Session 1 • Welcome & Introduction Vision for TEMI TEMI in Ireland Feedback about TEMI in TY • TEMI Enquiry Lesson Simulation Rolling Uphill (Engage and Explore) • Explore the 5E model of enquiry
Session 2 • Teaching to Motivate Two ways to teach Density Feedback from classroom experience Importance of Motivation
Session 3 • What is a Mystery? • Design TEMI Lesson TEMI Lesson Planner Available resources Present and share ideas with whole group • Pre-service Teachers- Final Year Project: Immediate reflections & insights
Session 4 • TEMI Lesson Resources Biology / Chemistry / Physics/TY Where to source ideas • Developing Shared Community of Practice Google + Forum • Tasks for Workshop 2 Details of teacher's responsibilities before next workshop in April 2014 • Review / Feedback / Questions

In the first Teacher Training Workshop, participating teachers will be provided with a resource folder containing all of the necessary documents for thier participation in the TEMI project. The contents of this folder include a list of all TEMI contacts and participants in Ireland, previously developed TEMI ideas, Lesson Planner templates to guide development of their own lessons, as well as selected relevant literature about IBSE and the 5E model.

Following this first workshop in January 2014, the in-service teachers will be asked to complete a number of tasks in advance of the next workshop in April. They will be invited to choose from the bank of developed TEMI classroom materials and will be required to implement at least 5 of these lesson ideas in their own classes. Once the teachers have become familiar with the TEMI teaching approach, they will then develop and implement at least 2 new TEMI lessons.

It will be important to gain feedback from the teachers' experiences of teaching enquiry with a TEMI focus and so teachers will keep a reflective diary, in which they will be asked to complete a one page reflection after the implementation of each TEMI lesson. Pupil questionnaires will act as another form of data collection tool and teachers will be requested to administer these to their pupils at the end of their TEMI lessons. The feedback and data attained through this will be used to inform the changes and improvements for subsequent workshops.

The second day of the workshop, was held in April 2014, and focused on the sharing of experiences of implementing the TEMI approach, and evaluating the effectiveness of the approach, as well as generating new ideas. The PSSTs were also able to describe the evaluation of their materials, which were trialled during their teaching practice in Autumn 2013). Since the workshops for cohort 1 described above, two more cohorts have completed their workshops. The content of the workshops was revised in the light of the experience and feedback from cohort 1 and then again after cohort 2. For cohorts 2 and 3 an local actor was brought in to talk about showmanship.

c) Sustainability

In order to ensure the sustainability of this IBSE project, it is intended to adopt a cascading mechanism, whereby more than one teacher from each participating school (through the 6 cohorts) will be invited to take part in the project.

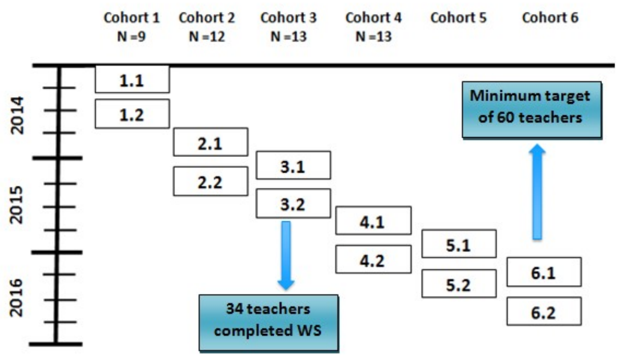

Figure 2 The sequence and structure of the workshops

For example, Teacher 1 from School A will participate in cohort 1 and Teacher 2 from School A will participate in cohort 2. (See Figure 2 above.)

In this way both teachers can support each other to sustain their implementation of the TEMI teaching approach. It is hoped that this will also help to establish a TEMI approach to enquiry in their schools. Participating teachers will also be encouraged to share their ideas and resources with other science teachers in their school, and thus diffuse the TEMI approach into the school's science teaching and learning programme.

So far three cohorts have done the workshops and 3 more groups (cohorts 4, 5 and 6) are planned between September 2015 and March 2016. **We are still recruiting teachers and schools for cohorts 5 and 6.** To apply you need to have at least 2 science teachers in the school , who are interested in doing the project, and a supportive Principal. Send an email to Peter Childs at peter.childs@ul.ie and we will send further information. To participate in TEMI, the school Principal needs to fill out a commitment form and nominate the two science teachers who will take part. This should be done as soon as possible in order to take part in the two remaining cohorts. One teacher from each cohort will be invited to the final conference in Leiden, NL in April 2016. All participating teachers will be invited to a national conference to conclude the project, probably in early June 2016.

In addition to this, a TEMI Google discussion forum and TEMI Google Drive™ folder have been developed. The aim of the Google Forum™ is to allow teachers to easily interact with each other online and to share their experiences of implementing TEMI lessons. The TEMI Google Drive™ folder, which is an online cloud storage facility, will serve as a storage bank for the curriculum materials. This will be continuously added to by the participants and team members throughout this project. It is intended that all involved members of the TEMI project will continue to use and develop TEMI-style materials after their own workshops are completed and all participants will be able to use the resources after the project has ended.

Conclusion

On a final note, there is great potential for a significant impact of this TEMI project on the national science curriculum in Ireland. Currently, a new Junior Cycle education framework has been developed, which is centred on placing learners "at the centre of the educational experience" [7]. This framework focuses on "Key Skills" such as "Being Creative" and "Managing Information and Thinking" [8], which directly align with the objectives of this TEMI project.

There are also proposals in place for developing the Senior Cycle science curriculum. Draft syllabi have been produced in the three main sciences - physics, chemistry and biology - and these too have been based upon "Key Skills" like the "Critical and Creative Thinking" skill [9]. The focus on "Key Skills" in the proposed educational frameworks creates a strategic opportunity for the implementation of the TEMI teaching and learning approach nationwide.

Dissemination of the project materials has so far been limited to teachers in participating schools, although anyone can access the project website (www.teachingmysteries.eu). At the conclusion of the project the TEMI materials developed in Ireland will be made available to all interested teachers. At the very least we hope that TEMI will introduce science teachers to the importance of engaging their students at the start of the lesson, and give them practice in doing this and access to a bank of ideas. Developing and using ways to engage students more in science will hopefully improve motivation and lead into successful lessons, even if the whole 5E model is not used. Better engagement by students in science is worthwhile aim in itself.

Acknowledgements:

This work was supported by the European Commission under the FP7-Science-in-Society-2012-1, Grant Agreement N. 321403

References:

[1] Bybee, R., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness.* Colorado Springs, Co: BSCS.

[2] TEMI (2013), 'What is a mystery?', [online] available: http://teachingmysteries.eu/en/resources/ [accessed 29 July 2015].

[3] Liem, T.L., 1990. *Invitations to Science Inquiry*, 2nd. Ed. Science Inquiry Enterprise

[4] O'Brien, T., 2010. *Brain-powered science: Teaching and learning with discrepant events*. Arlington, VA: NSTA Press

[5] Department of Education and Science (1993), *Transition Year Programme, Guidelines for Schools*, Dublin: Department of Education.
[6] Lemov, D., Woolway, E., Yezzi, K. and Heath, D. (2012) *Practice Perfect: 42 Rules for Getting Better at Getting Better*, San Francisco: Jossey-Bass
[7] Department of Education and Skills (2012) *A Framework for Junior Cycle*, Dublin: The Department of Education and Skills.
[8] NCCA (2013) *Key Skills of Junior Cycle*, Dublin, available online: http://www.juniorcycle.ie/NCCA_JuniorCycle/media/NCCA/Documents/Key/Key-Skills-Overview-Feb-2013_screen.pdf [accessed 29 July 2015].
[9] NCCA (2012) *Senior Cycle Science: Report on the Consultation, Dublin, available online:*http://www.ncca.ie/en/Curriculum_and_Assessment/Post-Primary_Education/Senior_Cycle/Consultation/Science_Consultation_Report.pdf [accessed 29 July 2015]

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Flipping classrooms with 14-16 year olds

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Kristy.turner@manchester.ac.uk

Introduction

Flipped lesson methodology has been gaining exposure in the educational press in recent years. With many students owning multiple internet enabled devices and increasingly using the web to find subject specific content, elearning materials are becoming a useful tool in supporting a flipped classroom. In this project the use of elearning materials in a flipped classroom model was trialled with boys in the 14-19 age range. Initial trials focused on the older students but the greatest impact was seen with boys in the 14-16 age range (GCSE years in the UK).

With the 14-16 year olds, all note taking activity was removed from the classroom for several topics in the syllabus, except where the homework pattern did not allow this. In this case note taking was done from the elearning materials in class before moving onto the class work. Time in class was spent on other activities, experiments and discussion as well as tasks commonly set for homework such as past exam questions.

Technical details

Homework activities were set in the form of screencasts. These were recorded using Camtasia Studio software on a laptop computer fitted with a Logitech USB microphone and a Bamboo graphics tablet. The screencasts took the form of the teacher talking and writing, on a blank PowerPoint screen, similar to the same way content would be delivered on a whiteboard in the classroom. Some screencasts included interactive quiz content in the form of multiple choice questions at the end of the content. The results of these quizzes were not reported to the teacher (although this is an option). The screencasts were shared using the Techsmith video hosting site www.screencast.com, using specific links that were emailed to the students prior to the homework activity. Occasionally the screencasts were accessed in class when they did not fit in with the students' homework schedule and students did this through their school iPad. Outside of school the students used a variety of methods to access the screencasts, their school iPad, desktop and laptop PCs at home and also mobile phones. Few technical difficulties were reported and those that were reported were easily overcome by switching devices. The students took notes from their electronic device into their school exercise book, the intention being that this would be a blended technology.

Students' responses to the project

The boys' responses were overwhelmingly positive. They preferred the screencasts to other types of homework and the majority preferred taking notes at home in their own time for a variety of reasons. The boys were asked to send me an email to tell me what they thought of the screencasts and the concept of the flipped classroom model, allowing them a free response. Several students said they liked the screencasts because they allowed them to work at their own pace "*I found the homework method was very* *useful because I could work at my own speed without interruption from my peers. I felt it helped me understand the subject more clearly..*" They recognised that the classroom environment, no matter how quiet or well managed was often distracting and distractions could be avoided at home. *"The audio explanation is also a lot easier to understand than in class due to there being no noise to distract you and other pupils asking questions that can sometimes complicate things, you can also ask your questions that you need to in the next lesson or at a break or lunchtime if you seriously don't understand it."* The boys also recognised the time gained from using the screencasts and how lessons changed as a result "I *really like the concept of the whole idea, how we can make notes at home on a video that you have made for us, so that we can do practicals and experiments in class…*" A pleasant surprise that arose from the project was the impact of the screencasts for students who have special educational needs. N has Attention Deficit Hyperactivity Disorder and finds the classroom environment difficult to concentrate in "*The ipad video notes things are good, as i can take as much time as i need/want. Since i can do these at home it means i can use colours, which i don't bring to school (they're heavy). The video notes are better than doing them in class as there are less distractions from people asking silly/irrelevant questions. I can also write down questions for the next lesson, if i ever need to do. Since they are also written, that means i can try and keep up with it.* J has dyslexia and finds it difficult to take notes down accurately from the board. *"They are very good at helping me learn, as I am a visual learner and an auditory learner. It is a lot more helpful than ordinary homework as it's like taking the lesson home with you. However it could be improved with a bit of colour for key words, but it's still better than ordinary homework."*

Conclusions

As a teacher I have found implementing a flipped classroom model very interesting and much less difficult and time consuming than I had anticipated. Initially the screencasts took me a disproportionate amount of time to prepare but I quickly became familiar with the software and overcame my nerves about recording myself. I felt the students were warmed up to the learning, they knew something when they arrived at the lesson and were often keen to ask questions about their homework. The questions they asked were relevant and didn't interrupt the flow of learning because of the time gained in class. The time we spent on experimental work and the follow up was significantly increased which engaged the boys. Feedback from parents at parent-teacher meetings was positive, they could see their son doing homework, it was visible to them and this reassured them about the use of screen technology in supporting their son's learning. It was initially very challenging to devise activities that filled the class time since there was almost no 'teacher talk' but after the initial lessons we found a good rhythm for the format of our lessons.

Overall the project has had a significant impact on my professional practice as a teacher of chemistry. I was initially sceptical about the concept and how the boys would respond but it was quickly shown that the concept worked well in my classroom both for me as a teacher and for the boys I teach. The creation of a more inclusive classroom environment for able learners with SEN was an unexpected bonus. I will continue to develop this approach in the future and am now extending this to work with the younger boys.

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Dr KristyTurner is a chemistry teacher in a school in Bolton, U.K. and also works with the Chemistry Department at the University of Manchester. She was an RSC Teaching Fellow and her visit to Ireland was supported by the RSC.

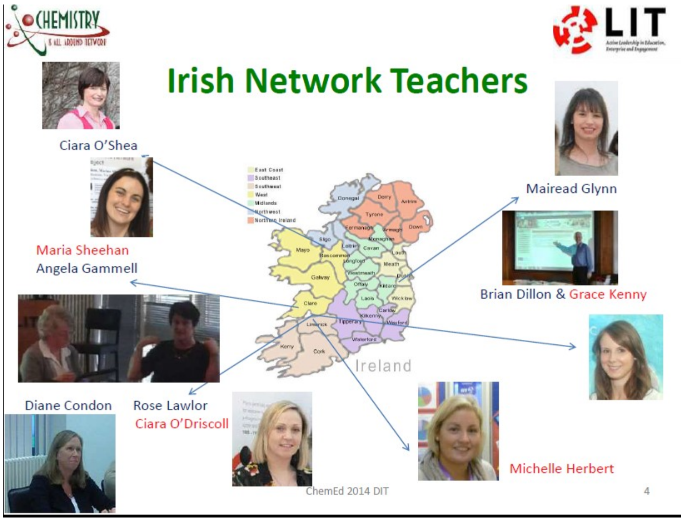
Chemistry is all Around Us: three years of resource gathering

Marie Walsh (LIT) and Diane Condon (Árd Scoil Rís, Limerick)
Marie.walsh@lit.ie **and dicondon@gmail.com**

The Chemistry Is All Around Network Project involved thirteen partners from eleven European countries. Two of the partners were involved in overall project management and in development and maintenance of the web portal. The remaining eleven were involved in carrying out the project activities, from gathering a local network to dissemination at local, national and transnational level. The aim of this Comenius-funded project was to encourage lifelong learning in Chemistry. To this end a collection of links to ICT-based resources has been gathered on the web portal at www.chemistryisnetwork.eu However, the portal is more than just a collection of links to resources as it has gathered papers and publications from eleven partner countries that show how difficulties with motivation and dissemination of research and resources arise across all countries.

Project managers from eleven countries at transnational meeting in Limerick

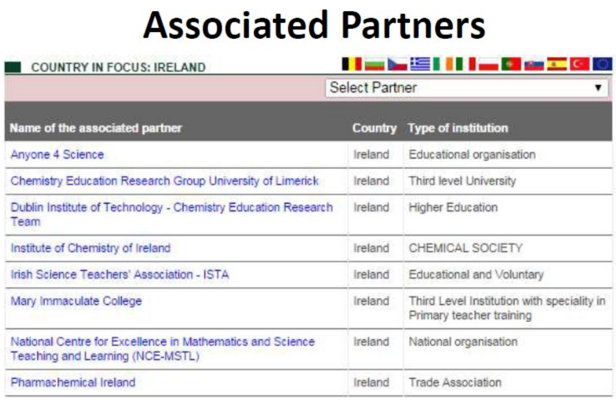
Each of eleven partners gathered a network of teachers and experts to complete the project activities.
The Irish teachers who participated are shown below:



Irish network teachers

The project had a three year lifespan and each year had a general theme: Student Motivation, Teacher Training and Successful Experiences. A number of publications from each country were gathered and a paper summarising each theme in the country produced. Each group held workshops to discuss the issues pin-pointed in the publications and papers. The project managers from each country then brought the results of each activity to transnational meetings. In addition, each country gathered links to resources which were freely available to download, and wherever possible in English.

The experts were drawn from a number of organisations, and as the project progressed associated partners joined the network and attended workshops and a transnational conference in Limerick. The associated partners all have on-going vested interests in promotion of science/chemistry teaching and learning.



Associated Partners

COUNTRY IN FOCUS: IRELAND

Select Partner

Name of the associated partner	Country	Type of institution
Anyone 4 Science	Ireland	Educational organisation
Chemistry Education Research Group University of Limerick	Ireland	Third level University
Dublin Institute of Technology - Chemistry Education Research Team	Ireland	Higher Education
Institute of Chemistry of Ireland	Ireland	CHEMICAL SOCIETY
Irish Science Teachers' Association - ISTA	Ireland	Educational and Voluntary
Mary Immaculate College	Ireland	Third Level Institution with speciality in Primary teacher training
National Centre for Excellence in Mathematics and Science Teaching and Learning (NCE-MSTL)	Ireland	National organisation
Pharmachemical Ireland	Ireland	Trade Association

Associated partners who joined the Irish network

Irish network experts

As is required of all projects, evaluation was carried out with regard to each step, and the teacher evaluations were largely positive. Teachers noted that 'an excellent range of resources have been built up' and they spoke of the 'range and variety of resources' as well as the benefits of 'access to experiences in other countries'. Drawbacks included lack of time within syllabus constraints, and difficulties with language and translation where the resources listed were not in English. It is also notable that not all students have access to ICT outside school, which diminishes the use of resources for homework or motivation outside the school setting. However, the fact that each resource or publication was categorised, listed with a description, and included a review by at least one other network member was seen as very useful.

The Chemistry is all around us web portal

Diane Condon spoke of her experiences as a teacher participating in the project. She felt there was great value in teachers having the opportunity to discuss issues and research outputs with third level lecturers and researchers. The sharing aspects of the workshops and the portal were useful and made her think about commonalities across Europe. She described the easy navigation of the portal and mentioned some of the useful resources linked.

Diane's general experience of the project was echoed by others in feedback given at workshops:

'I use the teaching resource section of the portal almost every day when preparing classes or looking for new ways to teach a particular topic. The interactive resources are particularly useful, as ICT is now an integral part of the teaching and learning experience.'

Mairead Glynn

'Each time we met I left feeling energised and enthusiastic about teaching and had lots of new ideas to try in the classroom.'

Michelle Herbert

'Being involved in a European project of this nature has been a very worthwhile experience. It provided both my students and me with more resources and a greater

understanding of how chemistry could be taught and learned in the classroom.'

Ciara O'Shea

There is no doubt there are common issues across Europe with regard to motivating students, training of science teachers and underpinning successful initiatives. It is interesting to hear if or how these issues are being addressed. Recurring points for debate included Misconceptions transmitted from teachers to students, Concurrent versus Consecutive Training, the value of structured Mentoring, the need for Probation and the vital importance of (compulsory) Continuous Professional Development.

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For further information about the project please check the project portal at www.chemistryisnetwork.eu or contact Marie.Walsh@lit.ie There is also a Facebook page to try to ensure sustainability of the project. Check out Chemistry is all around network Ireland on Facebook https://www.facebook.com/chemistryisallaroundusnetworkIreland - this will hopefully be a resource that will allow sharing of ideas and teaching tips as well as links to resources.

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Marie Walsh was the Irish coordinator for the project and is a lecturer in science at Limerick Institute of Technology; Diane Condon is a science teacher at Árd Scoil Rís, Limerick.

SCIENTIX
The community for science education in Europe

Scientix

Mary Mullaghy (ISTA and TCD)
mmullaghy@gmail.com

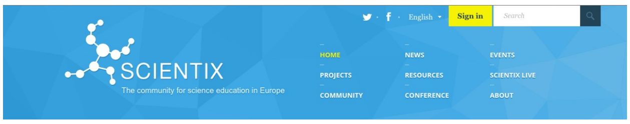
Introduction

At the beginning of the 21st century it was acknowledged that there was a deficit of STEM professionals to support the growing economic needs in Europe. The **Rocard Report** *"Science education now: a renewed pedagogy for the future of Europe"* published in 2007 identified the need to address the falling interest of students in STEM education. He highlighted the fact that to redress the trend of falling student interest science, teaching models needed to change radically and recommended a move towards inquiry-based methods to provide the means of increasing interest in science.

Scientix was launched to facilitate the dissemination and sharing of know-how and best practices in science education to a wider audience of teachers, educators, researchers and policy makers across Europe. It promotes and supports a Europe-wide collaboration among STEM (science, technology, engineering and maths) teachers, education researchers, policymakers and other STEM education professionals. Teaching materials and research reports from European science education projects in the 30 participating countries are collected and disseminated through the Scientix website. The Scientix website is a free-to-access and free-to-use portal. To access all resources users are simply required to register.

Scientix portal

The philosophy of the project is summarised by the motto **"Search Find Engage"** This motto emphasises the shift from the earlier website where information was simply disseminated to end users to a more dynamic and user-centred website.



What does Scientix do?

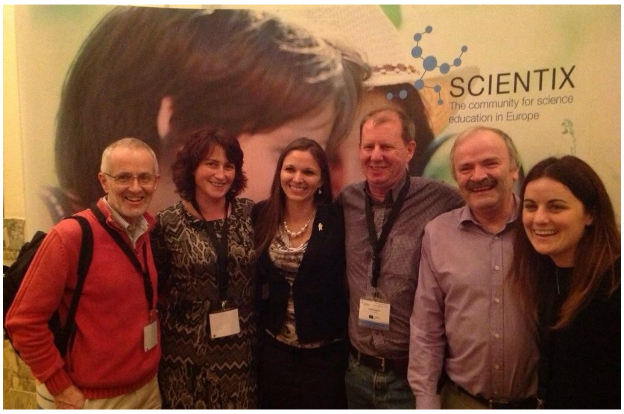
SCIENTIX promotes and supports a Europe-wide collaboration among STEM teachers, education researchers, and other STEM education professionals.

Scientix is managed by European Schoolnet (EUN) on behalf of the European Commission. It

was was established in 2009 and was divided into two phases known as Scientix 1 and Scientix 2.
In its first phase (2009-2012), the project built an online portal to collect and present European STEM education projects and their results, and organised several teacher workshops.
In the second phase (2013 – 2015) the goal was to expand Scientix at a national level to the 30 participating countries. Through the network of the National Contact Points (NCPs) and Teacher Ambassadors, Scientix aims to reach out to national teacher communities, and contribute to the development of national strategies for wider uptake of inquiry-based and other innovative approaches to science and maths education. The PDST is the national contact point for Scientix in Ireland.

Michael O'Leary, Mary Mullaghy & Willie McTiernan – Irish Scientix Ambassadors 2012-15

Scientix Conferences
The main networking event was the first Scientix conference, held in Brussels in May 2011, at which there were in excess of 300 attendees. The second Scientix Conference took place in Brussels in October 2014 and had over 600 attendees. Teachers and educationalists from all the participating countries were invited to attend - their flights and accoomodation were paid by Scientix. Amber Bell, NASA rocket scientist, was a keynote speaker and she will also be attending the ISTA Annual Conference in LIT April 8^{th}-9^{th} 2016 along with Prof Eric Mazur from Harvard.



John Daly, Mary Mullaghy, Amber Gell (NASA), Paul Nugent, Michael O'Leary, & Maria Sheehan at Scientix 2 Conference in Brussels in October 2014.

Scientix website
The Scientix website consists of the following sections:

Scientix Projects
The projects section of the Scientix portal presents European science, maths and technology education projects. It is possible to search for projects by topic, target group or by country. Each project contains three pages of information: A general description, research information and teacher information.

Scientix Community
The Scientix community is a platform for Scientix users to network, share experiences and ideas, and discuss the projects. Here you can avail of an online meeting room for up to 200 participants free of charge. There is also a discussion forum and a chat room. The discussion forum space is open to everyone; however, it is necessary to register on the Scientix portal in order to participate in the discussions. The Scientix chat tool is a quick and easy way to interact directly with other users. The Scientix Moodle platform offers the opportunity to follow various online training courses for teachers interested in improving their skills, to learn to use tools that can bring a new dimension to their science classes, deepening their knowledge on specific topics, or follow an introductory course on a totally new subject.

Scientix News
In the Scientix news section, you can find current national and international news on science education projects, events, and competitions. The News can be searched by topic, target group, language or country related to the item, and an RSS feed is also available.

Scientix Resources
The Scientix resource repository allows you to find and download teaching materials, lesson plans, reports, studies, guidelines and training courses. Teaching material may be translated into Irish as soon as you are registered on the portal, subject to certain criteria.

Scientix Events
This contains an active calendar containing details of STEM related events happening in Europe.

Scientix Live
Here you will find information about face to face activities organized by Scientix e.g. webinars and workshops in European Schoolnet's Future Classroom Lab or at other venues. You can also find presentations at past events which are available via Slide Share.

Scientix Blog
People connected with Scientix (EUN colleagues & Ambassadors) will publish personal stories on science education in Europe.

Scientix Awards
The aim of the awards is to encourage STEM education projects to share their resources in the Scientix repository, and to support dissemination and uptake of innovative teaching and learning materials among teachers. All resources in the Scientix repository added within the time period given for each competition round will be eligible. The winners will be selected by an expert panel of Scientix Ambassadors, Deputy Ambassadors and independent experts in STEM education.
There will be up to four winners in each round: the best teaching material, the best learning material, and the best report (policy recommendation, research papers, etc.). The winning resources will be promoted on the Scientix website and highlighted in the newsletters and at Scientix events.

Sign up
You can sign up via their website to receive regular updates http://scientix.eu and stay in touch via Facebook https://www.facebook.com/Scientix and Twitter @scientix_eu

Scientix Newsletter
The Scientix quarterly newsletter delivers original articles on innovation in STEM education policy, research and practice. It brings the latest news from science education projects and from the Scientix community, and follows the development of European and national policies and initiatives. Each issue focuses on selected topics in science education and highlights presents related materials and activities.

Scientix Digest
Scientix Digest is a fortnightly newsletter, providing an overview of the latest updates on the Scientix portal. It features projects and resources recently added to the Scientix portal, and informs about upcoming events in STEM and related fields.

PDST / Scientix Funded Workshops

Scientix have funded physics, chemistry and biology workshops in Ireland. Details on http://www.pdst.ie/scientix
Email sciences@pdst.ie with any queries or questions

EC Commissioner Máire Geoghegan Quinn speaking about Scientix at the ISTA Annual Conference in NUI Galway April 2014.

Mary Mullaghy is a science teacher at Eureka Secondary School, Kells and a former Chairperson of the ISTA. She is currently on leave of absence doing research in science education at Trinity College Dublin, under the supervision of Dr Colette Murphy.

SciFest Science Fairs in Schools and Colleges

Sheila Porter (SciFest) sheila.porter@scifest.ie

The SciFest science fairs programme is a national initiative designed to foster a love of STEM in second-level students through active, collaborative, inquiry-based learning. Established as a pilot in 2006 it was launched nationwide in 2008. Entry to SciFest is open to all students; it is locally based and there is no entry fee, making it highly accessible and inclusive. Participation in the programme has grown at a phenomenal rate with a yearly average increase of approximately 24%. In 2015 over 7000 students participated, bringing the total number of participants since 2008 to over 32,000.

SciFest is all about encouragement and building confidence in students in their ability to do STEM. No investigation is too simple. It's also about capturing the students' imagination, encouraging them to think for themselves, work with others and develop strategies for learning which will accompany them throughout their lives. There are lots of ideas for projects on the SciFest website www.scifest.ie.

Teacher Mary Gorey from St Joseph's College, Thurles, Co. Tipperary being presented with the RSC School Chemistry Award by Kevin Healion (SciFest@College 2015 LIT Thurles)

SciFest operates at four levels: local, regional, national and international.

Local - SciFest@School: In-house SciFest science fairs are hosted by second-level schools throughout the school year. Support is provided by SciFest in the form of a SciFest Science Fair Toolkit, resources and BKMs on the SciFest website. This strand was introduced in 2011 and in 2015 forty schools hosted SciFest@School science fairs. Registration forms can be found at http://scifest.ie/scifestschool.

PharmaChemical Ireland Chemistry Award winners, SciFest@LIT, Andrew O'Connor, Aengus McGill and Aaron O'Callaghan, St Munchin's College, Limerick with their teacher Sara McGeer

Regional – SciFest@College: Fourteen Institutes of Technology and St Mary's College, Derry (in 2016 there will be an additional fair in DCU) host one-day regional SciFest science fairs between April and the end of the school year. These are open to all second-level students. A SciFest@College fair consists of a competition and exhibition of projects, a prize-giving ceremony, and may also include a selection of science talks, science demonstrations in the college laboratories and advice on careers in STEM. SciFest@College affords students the opportunity to visit a third-level college, view the facilities and get information on the various STEM courses available.

National: SciFest@SFI Discover. Overall winners from all of the SciFest@College events compete at a national final in Dublin in

November. In addition, five projects from the winners of the SEAI Award and five from the Boston Scientific Award at the regional events are selected to participate in the national final. Each exhibitor is presented with an Excellence in STEM award in recognition of their success at the regional fairs. There are also a number of travel awards presented at this event.

International: SciFest is currently affiliated to two international science fairs: the Intel International Science and Engineering Fair (ISEF) and the International Environment and Sustainability Project Olympiad (INESPO). SciFest first participated in Intel ISEF, which is held each year in America, in 2012. Winners of SciFest 2011, 2013 and 2014 won 5 major awards between them at the Intel ISEF. SciFest competed in INESPO in the Netherlands for the first time in 2015 and came away with a first place gold medal award; 47 countries participated.

The SciFest programme offers an innovative way for teachers to expose students to, and enhance their understanding of, STEM subjects. Own choice of topic, collaboration, hands-on activities, presentation skills and recognition of work done are all attractive aspects of SciFest. The emphasis on real-world problems helps make STEM relevant to all students. SciFest provides an excellent platform to promote an interest in chemistry. Each year at each of the regional venues PharmaChemical Ireland sponsors an award for the project with the best chemistry content and to further promote chemistry The Royal Society of Chemistry (Education Division) sponsors a school chemistry award.

See www.scifest.ie for more details.

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Workshops
WS3 Crafty covalent bonding

Kristy Turner (RSC Teacher Fellow)

Creative covalent bonding lesson plan

Covalent bonding is the sharing of electron pairs in order for atoms to gain a full outer shell. In this lesson this process is modelled using beads and pipe cleaners.
Materials needed

- Pack of pipe cleaners
- Pack of coloured beads
- Scissors

I picked up 2 packets of beads and 2 packets of pipe cleaners (called chenilles for some strange reason!) in the kids craft section at Asda for £1 each. The whole set of materials was able to do 2 classes with students working in pairs.

Medium difficulty

Get students to draw some Lewis dot and cross diagrams showing the overlap of outer electron orbits for some covalent molecules. Introduce the *rules* for modelling.

- Each pipe cleaner ring must have the right number of beads (electrons) for a full outer shell (most of the time this is 8, but for H it is 2)
- Where there are covalent bonds the beads (electrons) must be held by the orbits (pipe cleaners) of both the atoms in the bond.

Get students to come up with their own structures to model or direct them according to appropriate difficulty.

Advanced difficulty

Brainstorm with students how they could use pipe cleaners and beads to model the structures of covalent molecules. Get them to come up with some rules or with some early models to criticise. Eventually this should lead them to the rules above.

They can then evaluate their models. Things to think about are how accurately the models show electron distribution, atomic radius. They can guess what each other's molecules are.

Example of a finished product

The model shown is of sulphuric acid.

- The green pipe cleaner represents the sulphur with its electrons represented by purple beads (there are 6).
- The white pipe cleaners with pink beads are the oxygen atoms. They are doubly bonded as shown by the alternating purple and pink beads showing electron sharing.
- The blue pipe cleaners are the O atoms of the OH with their 6 electrons represented by white beads. Finally the white pipe cleaners represent the H atoms with the electrons represented by pink beads.

Here the student has attempted to make some reference to the radius of the atoms.

WS4 Making and using stop-motion animations to help in the teaching and learning of chemistry

Maria Sheehan (PDST) mariasheehan400@gmail.com

What is stop motion animation?

Stop motion animation is an animation technique that makes a physically manipulated object appear to move on its own. The object is moved in small steps and each movement is individually photographed, when the series of frames are played as a continuous sequence it creates the illusion of movement.

How can stop motion animation be used in the Chemistry class?

There are a number of uses for stop motion animation in the teaching of Chemistry. Stop motion animation can be used to:

1. Learn a concept
2. Find out more about an idea
3. Restructure thinking around an idea and address misconceptions
4. Communicate understanding
5. Compile a group record

How does it work?

To run a stop motion animation activity in your classroom the following lesson structure may be of help:

Step 1: Plan the storyboard containing 7 or 8 scenes that would be assembled to form the animation. This step can also be used to develop student's literacy skills. Figure 1 shows a template that could be used as a storyboard:

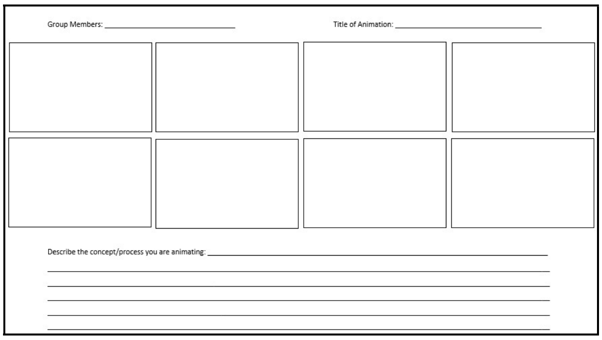

Figure 1: Storyboard Template

Step 2: Construct each scene using sketches, modelling clay, molecular models, or anything else suitable. Figure 2 shows an example of how a scene to explain free radical substitution can be set up using molecular models and plasticine.

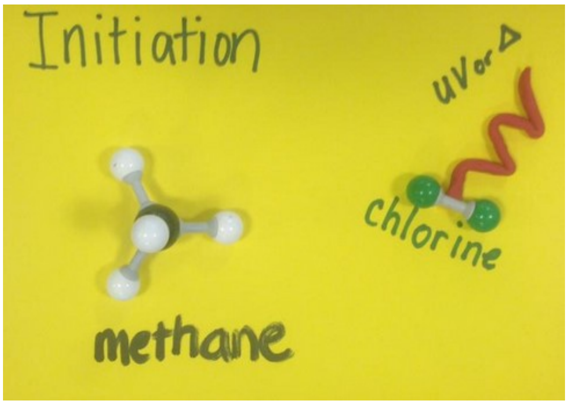

Figure 2: Setting up a scene to explain free radical substitution

Step 3: Take photos of each scene with a digital camera or camera phone
Step 4: Import the photos into a software package and produce the animation. Examples of software packages to produce stop motion animations include:

- Windows Movie Maker (free software)
- Photostory
- Animoto
- Lapse It (IOS & Android))
- iMotion (iOS)
- Clayframes (Android)
- Samanimations (this software is not free)
- 2animate (this software is not free)

Recommendations when using stop-motion animation:

1. Students should work in groups of maximum 3 people
2. If the stop motion animation deals with particles these should be kept to a maximum of 12 particles in order to notice specific movements. For example if students are producing a stop motion animation to show the phase change in water from a solid to a liquid then they should use a maximum of 12 water particles in their animation.
3. The camera should be held in the same position each time. A retort stand in the school laboratory can be used to keep a mobile phone in the same position.
4. Encourage students to use the various effects of the software package they are using to develop key skills of managing information and thinking and being creative.

Examples of Chemistry topics in which stop motion animation can be used:

- Produce an animation to illustrate the fractional distillation of crude oil
- Produce an animation to explain the Bohr Theory
- Produce an animation to illustrate the diffusion of Ammonia and Hydrochloric Acid to form Ammonium Chloride
- Produce an animation to explain how a Mass Spectrometer Works
- Produce an animation to explain how the bonding in Sodium Chloride
- Produce an animation to explain Charles' Law
- Produce an animation to explain Boyle's Law
- Produce an animation to explain how a catalytic converter works
- Produce an animation to illustrate the reaction between Methane and Chlorine (Free Radical Substitution)
- Produce an animation to illustrate the reaction between Ethene and Chlorine (Ionic Addition)

Figure 3 shows an example of a task card used during the stop motion animation workshop at the ChemEd-Ireland conference 2014.

Figure 3: Task card for stop motion animation activities

This list is not exhaustive and many more topics can be developed using stop motion animation.

The benefits of using stop motion animation in the Chemistry class:

The process involves group discussion on content and sequence. This means they need to talk out what is happening, what to choose to put in each scene, and why they put one scene before or after another. The technology – taking photos, importing and producing – is quick and easy enough and does not to distract from the job at hand: explaining chemical concepts. The product itself is also a useful for revision, assessment or critique. Using stop motion animation provides an interesting alternative to posters or presentations and the group element requiring students to discuss the chemistry of the concept is a real added value of this approach.

Figure 4: Participants at the ChemEd 2014 workshop on stop-motion animation

□

Dr Maria Sheehan was seconded to the PDST for 2 years (2013-2015) and in Sept. 2015 is returning to teach at St. Caimin's Community School, Shannon.

Diary

2015

41st ChemEd
28 July – 1 August
Kennesaw, Georgia, USA
http://ccpe.kennesaw.edu/chemed/

45th IUPAC World Chemistry Congress
9 - 14 August
Busan, S. Korea (KR)

11th ESERA
Science Education Research: engaging learners for a sustainable future
31 August – 4 September
University of Helsinki, Finland
www.esera2015.org

45th IUPAC World Chemistry Congress
9 - 14 August
Busan, S. Korea (KR)

ChemEd-Ireland
17 October
UCC, Cork
d.kennedy@ucc.ie

2016

ASE Meeting
University of Birmingham, Birmingham, UK
http://www.ase.org.uk/conferences/annual-conference/

ISTA Conference
8-10 April
Limerick Institute of Technology, Limerick
www.ista.ie

Primary Science Conference
9-11 June
Waterfront Hall, Belfast
www.primaryscienceconference.org

ICASE World Science and Technology Education Conference
1-5 November
Antalya, Turkey
http://www.icase2016.org/

If you know of any relevant conferences or events of interest to chemistry teachers, please send in details to:
peter.childs@ul.ie
*****

Teaching is about more than content

One looks back with appreciation to the brilliant teachers, but with gratitude to those who touched our human feelings. The curriculum is so much necessary raw material, but warmth is the vital element for the growing plant and for the soul of the child.
Carl Jung

A Periodic Table of Limericks #5

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Boron, B

The compounds of this metalloid burn with a soft green flame,

The hardness of its nitride…its abrasive claim to fame.

Heat-stable borosilicate,

Watch borax cleans clothes delicate,

Its acid, gentle on the eyes, yet insects fear its name!

Notes:

The compounds of this metalloid burn with a soft green flame,

Boron is classed as a "metalloid", i.e. a substance with properties that are part metal and part non-metal. Many boron compounds burn with a tell-tale soft green flame.

The hardness of its nitride…its abrasive claim to fame.

Boron nitride (B_2N_3): A hard, lustrous, heat-resistant industrial abrasive.

Heat-stable borosilicate,

Borosilicate, better known as Pyrex® glass, contains boric oxide (B_2O_3) which makes it tough and heat-resistant; ideal for lab glassware and kitchen cookware alike.

Watch borax cleans clothes delicate,

Borax – sodium (tetra)borate, $Na_2B_4O_7.10H_2O$ – helps to "soften" the water when washing clothes, making it easier to "whip up" more suds! It also stabilises (or "buffers") the pH of water. This helps to promote the chemical reactions involved in cleaning.

Its acid, gentle on the eyes, yet insects fear its name!

Boric acid (H_3BO_3) is a weak acid ... so much so that it finds use as a mild antiseptic and even as an eyewash. Though safe for mammals it is toxic to insects, therefore making it a useful insecticide.

When is an experiment not an experiment?

Peter E. Childs
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"The ritual of the laboratory must not be confused with the spirit of science. The spirit of science cannot be weighed and measured, even if weighing and measuring are necessary for tracking it down. It is not enough to track it down, it must be captured; and not infrequently it evades capture because the reason is lethargic and the imagination dull." (Westaway, 1947, p. 11)

Introduction

When is an experiment not an experiment? This is not a trick question, but an experiment is not an experiment in the true, scientific sense of the word:

- if you know the answer before you begin;
- if it is just an exercise in following a recipe;
- if it if just copying a procedure from the textbook into your laboratory notebook; if it is just skills acquisition;
- if it is just a mandatory experiment without fitting into the teacher's curriculum;
- if it is watching an experiment on a video or DVD;
- if it is a 'dry lab' experiment, involving processing data rather than obtaining data by investigation;
- if it is a computer simulation of an experiment (as distinct from datalogging).

You may be able to think of other examples of activities that make an 'experiment' not an experiment at all. This is what Henry Armstrong wrote in 1910 about the importance of experiments in teaching science in schools:
"If boys and girls left school properly aware what an experiment is, what is involved in making one, how far from easy it is to make a real experiment; if they acquired a true sense of exactness in work and argument: the teaching given in schools would be of great value in after-life, as life is one big never-ending experiment. I see no reason why there should be school laboratories if the main purpose of them be not to give training in the art of inquiry." (Armstrong, 1925, p. ix)

Practical work has been seen as an essential component of teaching science at both second (secondary school) and third level (university and college). However, this tradition is not as strong in some countries as others. It is particularly strong, for example, in the U.K. in schools, going back into the 19th century. It can be argued that the laboratory-based science education started with Justus Liebig in Germany, where he set up his research teaching laboratory in 1839. W.H. Brock (1979), the famous historian of chemistry, takes this as his starting date for formal science education.
"My starting date, 1839, is arbitrary. It is the year in which the German chemist Liebig moved into an enlarged laboratory at Giessen, enabling him to expand the output of students. We may take this as a symbolic starting point for the development of modern science education."

At the end of the 19th century in England, Henry Armstrong promoted his heuristic approach to teaching science, that is, through hands-on practical work by students with the aim of discovering the answers for themselves. His views were ahead of the time and are reflected today in the emphasis on inquiry-based science education (IBSE), e.g. in the PROFILES project and other EU-funded 'Science and Society' projects. There is direct line of descent from Armstrong to the Nuffield science projects of the 1960s, which re-introduced learning by discovery to a new generation of teachers and pupils. Brock (1973, p. 21) described Armstrong's heurism like this (emphasis in the original.)
"Armstrong's heurism embraced four intuitive theses. First, that what a child or student finds out for himself he remembers. Secondly, motivation and interest: if a student is interested and realises that something is worth learning he will do it more efficiently. Thirdly, but less clearly, the

learning situation must be graded – children will learn certain things better at different ages. Fourthly, that if children keep a carefully written record of their findings this will help to correlate their mental and verbal understanding and relate a student's scientific awareness to his study of the English language. The whole emphasis is on ***doing*** *in order to* ***understand."***

Armstrong himself defined his approach in this way (quoted in Westaway, 1947, p. 22):
"Heuristic methods of teaching are methods which involve our placing students as far as possible in the attitude of the discoverer – methods which involve their ***finding out*** *instead of merely being told things."*

Now there may be nothing wrong in some of the alternatives to the experiment, and they may have some specific teaching value in themselves, but don't let us fool ourselves into thinking we are teaching a scientific approach to problem solving, or the investigative approach to science, if we never give our students a chance to solve real problems or experiment for themselves.

Skill acquisition is an important part of practical work in science – students (and teachers) need to be able to use a burette, weigh an object, measure a current, dissect a frog etc. But these skills are only a means to an end – the end being the ability to conduct an experiment using those skills to solve a problem, provide an answer etc. Often we confuse the two aspects of experimental work and very often pupils are confused when we mix skills acquisition and using these skills – they can be overloaded by new information. It is better to teach the skills first (ideally in some interesting context) and then use or apply the skills to solve a problem, preferably several problems so that the skills become embedded. This is developed further in the section below (see Danger: overload!).

Too often 'experiments' are introduced in the textbook and by the teacher and everything is known from the start. Some textbooks tell you the results as well as the procedure – not a lot of point in doing the task then. Teachers often tell students what to expect and what they should observe, before they've done the 'experiment'. It becomes an exercise in verification rather than an experiment and at the end it is not unusual for students to copy out everything word for word from the textbook into their laboratory notebooks. They may well think, as I do, that you might as well eliminate the messy, expensive practical bit and just copy straight into the books (which I believe happens in some schools!) This particular approach to science should not be called experimental, as it isn't.

I give some ideas below of how one could approach practical work in a different way and in a different spirit – a spirit of enquiry and discovery, using a real experimental and investigative approach.

Encouraging and developing investigation skills

Most of the mandatory or prescribed, standard experiments done in school can be recast in the form of an investigation so that they become real experiments and opportunities for the students to discover something for themselves. In the section below I give some examples of standard experiments presented as investigations.

a) Ohm's Law rediscovered

It is much better, in my opinion, to present practical work as a problem, as a question, as a challenge – not as a cookery recipe or a verification exercise. This may mean that we cannot allow our students to see the textbooks or we must choose a different book that doesn't give away all the answers! For example, consider our old friend, Ohm's Law. This is usually presented as an exercise to verify Ohm's Law, which is usually clearly stated, with the graph, in the book.

Instead, why not ask the question: is there a relationship between current and voltage across a fixed resistance? If there is a connection, how are voltage and current related? How might we find out the relationship? There might be a discussion about how to measure voltage and current, how to set up a suitable circuit, what to vary and what to measure and how to record and present the results.

The students then go away (preferably in a small group) to set up the apparatus and collect some data on the relationship between voltage and current. This presupposes some familiarity with the simple circuits and electrical equipment. These results could be collected on the board. Is there any obvious trend? Does the current increase with increasing voltage or in what way? Would plotting a graph help? Which graph gives a straight line and what relationship does this

suggest? The teacher of course is guiding this discussion and feeding in suggestions, but the students do the work.
What is the end result? A statement of Ohm's Law, but one that the students found out through experiment!

This approach not only practises and develops experimental skills, but it also introduces and reinforces ideas about the Nature of Science (NoS) and about the presentation of results and the use of mathematics in science, all within the context of an interesting investigation.

b) The structure of a plant

How do we introduce the structure of plants? Often this is done by students studying the diagram in the book or on the board, drawing it into their notebooks and labelling the diagram.

How might it be done differently to develop observational and experimental skills? Bring in several kinds of flowering plants and give one to each group of students. Ask them to draw the flower and stem and to identify the different parts and see how many different parts they can find. This requires careful observation. They should also take the plant to bits step-by-step and identify the different components. Perhaps they could draw their plant and then stick the different parts on a sheet of paper, showing where they are found. The names of the parts have not yet been introduced. Then give them the labelled diagram and ask them to identify and label the parts on their flower. Now it is time for a class discussion. Did all the different plants have the same parts or not? A table could be drawn on the board to tick off the different parts identified for each plant. At the end of the lesson all the students should have first-hand experience of observing, identifying and naming the parts of plant and making a generalisation that all the plants they studied have the same basic structure. This is real science! Then they can draw and label the diagram of a typical flower. The lesson could then develop further to investigate the function of the different parts of a plant.

c) Introducing acids and bases and titration

The idea of titration can be introduced using droppers, dilute acids and bases and a range of indicators. (This presupposes the students have already met acids and bases and have used a simple indicator e.g. litmus or red cabbage juice to identify and classify household substances.) What colours do various common indicators have in acids and bases? Rather than learning off a list, get them to do it – set up test-tubes with a small amounts of acid in them, and a second set with small amounts of different bases. In pairs, add a drop or two of indicator to an acid and a base, and note the colours. They should draw a table with the name of the indicator and their colours in acid and base.

Now ask the question: what happens to the colour if I add a base to an acid? They should be able to guess that the colour will change. Why does it change and at what point will it change? Get each pair of students to measure 20 drops of acid using a disposable plastic dropper into a small beaker or test-tube, add a drop of indicator and note the colour. They should then add the base drop by drop into the acid, shaking between drops, until the indicator just changes colour. After recording the number of drops they should repeat the experiment to check if it takes the same number of drops each time. Does the indicator used make a difference? Get the students to do it again with a different indicator and if the indicators have been chosen properly, the two answers should be almost the same (within experimental error, i.e. within 1 or 2 drops).

What is going on? Clearly from the colour change the base is destroying the acid and at some point all the acid has gone and there in an excess of base. What they have discovered is an end-point and what they have done is a titration, although we haven't yet used the terminology. The students have also found out that bases destroy or neutralise acids. **What is formed?** The students don't know yet what happens when a base is neutralised by an acid. They can do the same experiment (using droppers) but without an indicator to the same end-point and then boil the solution to dryness to find that a white solid (a salt) has been produced, which when re-dissolved in water is neither acidic nor basic. **What has happened?** A new substance (a salt) has been formed when an acid and base react with each other. The teacher can then move on to write a simple word equation for what has happened and later to do titrations with a burette and pipette. But the idea of a titration and the role of an indicator should have been firmly established in the students' minds. The apparatus is simple and cheap, only small amount of chemicals are needed and a lot of work can be done in a short time. The method can be used to compare the concentrations of different brands of vinegar etc.

Danger: overload!

One of the problems in teaching science in school is overloading the students' short term memories. We try to do too much, too quickly and we wonder why the students cannot cope, why they don't understand what they're doing and why they often default to following the recipe or rote learning. In the example above about titrations, this is often introduced to beginners by expecting them to learn to use the equipment (which may be new to them and involves new skills); understand what a titration involves and the role of the indicator; and then doing the calculations, which use the mole concept, something students have great difficulty with. When we do it like this we are expecting students to do too much and mixing up learning manipulative skills and understanding the concepts behind titration. We wonder why they can't cope and don't understand what they are doing, but we have designed a learning experience which is too complex and overloaded. It is better to break down the task into smaller, self-contained sections and then put them together at the end.

1. First introduce the idea of acids and bases and indicators for identifying and classifying them.
2. Use droppers to introduce the idea of titration and the end-point and neutralisation.
3. Practise the skills of using burettes and pipettes to measure out volumes precisely, use pipette fillers, fill burettes etc. by measuring out volumes of water, weighing the water delivered and using the temperature and a table of density, work out the volumes delivered compared to what they should be. By repeating this simple procedure the students are introduced to the idea of accuracy (delivering the right amount) and precision or reliability (how reproducible the volumes are). The manipulative skills can be polished and precautions learnt in a non-threatening context.
4. We can now put the skills to use by doing a titration using dilute acids and bases for both safety and economy (0.01M strong acids and bases work well) to find a reliable end-point.
5. The volumes used and the concentrations can now be related to the equation and the number of particles (moles) of acid and base used. This can be done first with known concentrations to show that the end-point is reached when the number of reacting particles of acid balances that of the base. The titration can then be repeated to find an unknown concentration.
6. Finally, the students can be encouraged to devise an experiment, using their new skills, to analyse samples of vinegar and compare value-for-money on everyday products. For example, how do different bleaches compare for concentration of oxidant and value for money? What is the percentage of water in washing soda crystals? These experiments involve using standard laboratory skills to solve a real problem, where the answer isn't known by the pupils. Some school chemistry students in New Zealand analysed different drinks for Vitamin C and found that their samples of Ribena contained **no** vitamin C: the manufacturer was taken to court and fined for misleading the customer.

The overall strategy here is breaking a complex task into smaller tasks, which can be mastered separately, and then put them together at the end to solve a practical problem. Once the skills have been mastered they can be used to investigate interesting open-ended problems.

Some objections

Two main objections are often raised by science teachers when you try to encourage them to do more experiments and when you try to get them to use inquiry or discovery methods: lack of time and lack of resources, both of which have some validity.

a) The first objection is the lack of time and doing practical work, rather than reading about experiments in the books, does take more time and using inquiry takes more time than more conventional (follow the recipe) approach to practical work. This is usually true because it does take more time to investigate something, especially if the students are involved in the experimental design and planning, compared to doing a structured exercise from a worksheet. The main question, however, is whether this extra time is worth it in terms of what students get out of the practical work. It might well be a case that 'less is more' – that students will learn better laboratory skills, learn about the nature of science and learn more in-depth about some areas of science. The argument in favour is that teaching students how to fish is better than giving them fish, especially fish that has been prepared and cooked by someone else.

b) The second objection is the lack of resources and facilities to do practical work properly. Adopting an IBSE approach where all students are actively involved in practical work may well need more time in a laboratory, and more equipment and chemicals. However, a lot of real experimental work can be done with simple equipment and everyday materials and chemicals. I have heard teachers say that they don't let students in lower secondary school do practical work because 'they are not able to do it' and because 'there will be too many breakages and too much waste'. If we use this argument we would never do any practical work, because students only become able by doing and making mistakes and practising. In fact, the more practical work they do the more proficient they will become. Isn't this true in every other area of life from riding a bicycle, cooking and learning a musical instrument?

This is what Joseph Priestley wrote about the situation in England in 1790 (quoted in Armstrong, 1925, p. 20), remembering that at that time science was called natural philosophy and that scientists were natural philosophers.
".. I would observe that, if we want to lay a good foundation for a philosophical taste and philosophical pursuits, persons should be accustomed to the sight of experiments and processes ***in early life****. They should more especially be early initiated in the theory and practice of* ***investigation****, by which many of the old discoveries may be made to be really* ***their own*** *– on which account they will be much more valued by them. And, in a great variety of articles, very young persons may be made so far acquainted with everything necessary to be previously known, as to engage (which they will do with particular alacrity) in pursuits truly original."* (Emphasis in the original]

This is a rationale for introducing inquiry into school science education as early as possible – and it was written 225 years ago. **Truly IBSE is not new at all.**

A major barrier

The objections raised above need not be insurmountable, as 'where there is a will there is a way'. The attitudes of science teachers to practical work, deficiencies in their own training and their lack of experience of IBSE are greater barriers to the use of more inquiry-based experiments in schools. If a science teacher never experiences IBSE themselves in school or in university (where set, prescribed practical work is often the norm), receives little instruction to in teacher training or in CPD courses, goes back into a school system where inquiry is not practiced, encouraged or supported, then the likelihood of the teacher implementing IBSE in their own school and laboratory is small. We have to find some way of breaking this vicious cycle (Childs, 2014) which only serves to perpetuate the *status quo* and a traditional, didactic approach to teaching science, where an experiment is only an exercise and an investigation means following a recipe.

Conclusion

I hope I have given you a flavour of what teaching science experimentally might look like. It may take more time than copying out the answers from the book or board but I think there will more understanding and less regurgitation. After exposure to this approach the students will understand what science is about and how scientists go about investigating the world and how they find out the things written in their textbooks. They will have been exposed not only to manipulative skills (pouring and filtering) but also to thinking skills (how? why? what if?), which are the essence of real science. You never know, if exposed to real, experimental science then they might enjoy science more, they might understand it better and they might want to go on and study science further so they can ask more questions and find out the answers for themselves.

These ideas are not new or original – they have been around since the late 19th. century and were then known as the heuristic method and later on as discovery learning, and influenced many of the science curriculum projects of the 1960s and 70s, and in more recent years IBSE.

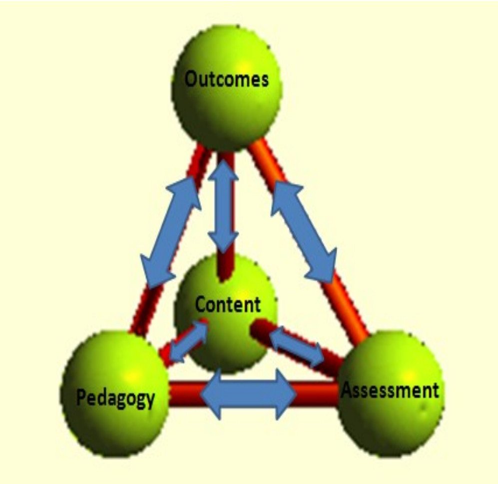

Figure 1: The four aspects of the science curriulum

To change the system we must first start with the teachers, and pre-service science teachers, in giving them the training and experience and the vision to implement IBSE. This cannot be done overnight or in a few short workshops, or through limited involvement in an EU project. Neither can it be done unless there are also changes in the curriculum – particularly in the content and expected outcomes, and in the assessment. Pedagogy usually conforms to the curriculum, not the other way round. The whole system (Figure 1) needs to be changed and there needs to be a consistent, integrated approach to every aspect of the curriculum, if we are to change the way practical work is done and to bring real inquiry into science teaching.

In the 21st. century it's surely time to put the experiment back into science.

References

Armstrong, H.E., (1925) *The teaching of scientific method and other papers on education.* 2nd. Edition. London: Macmillan

Brock, W.H., (1973). *H.E. Armstrong and the teaching of science 1880-1930*. Cambridge: Cambridge University Press.

Brock, W.H., (1979) From Liebig to Nuffield: A Bibliography of the History of Science Education, 1839-1974. *Studies in Science Education.* **2** (p. 68)

Childs, P.E., (2014) Breaking the vicious cycle in chemical education. In Proceedings *3rd Edition New Perspectives in Science Education*, ed. Pixel, Florence: Pixel 420-425

Westaway, F.W., (1947) *Science teaching.* London and Glasgow: Blackie

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Inquiring into the mysterious chemical garden

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The mysterious phenomenon of the chemical garden was already described in the 17th and 18th by the famous chemists Johann Rudolph Glauber or Johann Friedrich Wiegleb. Since then, this experiment became to be found in many collections of chemical show experiments. However, there are hardly any proposals on how to operate this phenomenon for teaching and learning in chemistry classes. This article suggests a few ideas of how this phenomenon can be inquired in chemistry teaching.

Introduction

In a glass beaker we are having a clear, colourless liquid, and on the bottom a layer of sand. Successively, differently sized crystals of various metal salts are placed therein. Once the salts reach the floor, a mysterious phenomenon happens: the crystals start to change their shape; it seems that they start to grow. Small plant-like structures emerge that grow upwards. Some metal salts turn into needles, others form tubers at the end of 'plant'. We can observe that the structures burst at the upper end and shortly thereafter close again slightly further back. Many of the crystals grow towards the surface so that they look like trees or grass. Other crystals only cover the floor, like a moss. Ultimately, a fascinating landscape of shapes with a blaze of colour results (Figure 1).

Figure 1: Example of a chemical garden

Here we describe a phenomenon that is known in the world of chemistry as the chemical garden (Roesky & Möckel, 1996). It has previously provoked a great deal of fascination for many people. It was described For the first time already in the 17th and 18th century by the famous chemists Johann Rudolph Glauber (1604-1670) and Johann Friedrich Wiegleb (1732-1800). It causes a big attraction so that it has even found its way into the literature, such as it was mentioned Thomas Mann's famous novel "Doktor Faustus" (Roesky & Möckel, 1996). It has become a famous show experiment in chemistry of which there are countless videos on the Internet, e.g. on YouTube. Although there are countless descriptions of how to create a chemical garden in books or on the Internet (e.g. Hoover, 2011, or Hermenstine, 2015), it seems that this fascinating experiment rarely found application in the means of solving the mystery behind the chemical garden by inquiry learning in chemistry classes.

Within the EU-project *TEMI - Teaching Enquiry with Mysteries Incorporated*, we are trying to take advantage of such fascinating phenomena in order to arouse the curiosity of students, so that they become interested in inquiring into scientific phenomena. For details on the TEMI project see a booklet by the TEMI project, which can be downloaded from www.teachingmysteries.eu (TEMI-Consortium, 2015). The chemical garden seems to be well suited for this purpose because it provides opportunities for self-directed, inquiry learning, as long as risky metal salts (such as nickel, chromium and lead salts) are avoided. Students can compare the behavior of various metal salts, vary the concentration of the solution or the temperature; but they can also inquire into the resulting structure with a magnifying glass or a microscope in order to learn about the solubility of salts or the emergence and function of semi-permeable membranes.

This paper presents selected ideas, by which the phenomenon of the chemical garden can be integrated into chemistry classes as a means of inquiry learning. For more selected information on the chemical background see e.g. Cartwright, Garcia-Ruiz, Novella and Otalora (2002).

Chemical background

The chemical garden emerges when certain metal salt crystals are placed in a water glass solution. Water glass is water-soluble sodium, potassium or lithium silicate. In this case, we use a solution of sodium silicate (sodium water glass). For the production of sodium water glass, fine quartz sand is heated with solid sodium carbonate to 1100-1200°C so that sodium tri-silicate is formed. If this is dissolved in water at 5 bar pressure and about 150°C, sodium silicate solution (water glass) can be obtained. If now certain metal salt crystals are added into the sodium silicate solution, the silicate anions form sparingly soluble compounds with metal cations, which coat the metal salt crystal with a thin layer of metal silicates. A semi-permeable membrane is formed. The membrane is permeable for water, but not for the metal cations.

A metal salt solution is emerging located in the space between the membrane and the crystal. The concentration of the dissolved salts within the membrane structure is greater than outside the shell. By osmotic pressure water permeates from the surrounding solution through the membrane. The result is an overpressure which causes the silicate layer to burst. Due to density differences within the structure this phenomenon takes place mainly at the upper end of the sheath or tubule. Since the concentration of the metal salt in the upper part of the membrane is smaller than in the lower part, the structure at the top is thinner and can burst more easily. In the case of a burst, the metal salt solution comes into contact with the sodium silicate and reacts immediately to restore the membrane again. This process repeats itself many times and so the structures grow.

Inquiring into the chemical garden

The TEMI project intends to foster inquiry learning. The chemical garden offers rich opportunities for this. For the students it is helpful to have some basic knowledge about salts and their solubility, and that there are sparingly soluble salts. Students should also know or learn about the concept of semi-permeable membranes, osmosis and osmotic pressure.

The chemical garden as a demonstration experiment

Materials/chemicals: beaker (you also can use old jam jars or plastic cups), measuring cylinder, spatula, glass rod, calcium chloride di-hydrate, iron (III) chloride, copper (II) chloride di-hydrate, copper (II) sulfate penta-hydrate (subject to availability other metal salts), sodium silicate solution (water glass), sand

Procedure:

1. Mix 100 mL of water glass with 50 mL of water (or other volumes in the ratio 2:1). Stir well.
2. Put into the beaker a layer of sand so that the bottom is covered. Now carefully fill in the water glass solution.
3. Add various metal salt crystals and, if necessary, push onto the ground with a spatula. Tips: Copper (II) sulfate is a good ground cover, as this salt does not form very high crystals. Iron (III) chloride shows strong growth, thus you should not take too much of it.

Observation *and explanation*:

Figure 1 shows the result of the experiment. The explanation can be found above in the description of the chemical background.

The chemical garden as a student exercise

Materials/chemicals: small plastic beakers (0.02 L), measuring cylinder, spatula, glass rod, calcium chloride di-hydrate, iron (III) chloride, copper (II) chloride di-hydrate, copper (II) sulfate penta-hydrate, sodium silicate solution (water glass), sand

Procedure:

1. Mix 10 mL of water glass and 5 mL of water (or other volumes in the ratio 2:1). Stir with a glass rod.
2. Give each a thin layer of sand into several small plastic beakers, so that the bottom is just covered. Now carefully fill in the water glass solution.
3. Now crystals or a spatula tip of each of the metal salts are added into one of the beakers and, in case, are pushed onto the ground with the spatula.

Observation and explanation:

Figure 2 shows an example of the observation with copper sulfate. It is also to be seen that during the formation of silicate structures gas bubbles occur. It is the air which has been included or connected to the crystals and then is released during the dissolution process.

Figure 2: Copper (II) sulfate in water glass solution

Inquiring into the crystals

Materials/chemicals: copper (II) sulfate penta-hydrate, sodium silicate solution (water glass), sand, water, glass rod, graduated cylinder (25 mL), magnifying glass, microscope, plastic cup (0.02 L), spatula.

Procedure:

1. Mix 10 mL of water glass and 5 mL of water (or other volumes in the ratio 2:1). Stir with a glass rod.
2. Give a thin layer of sand into a small plastic beaker, so that the bottom is just covered. Now carefully pour in the water glass solution.
3. Some small crystals of copper (II) sulfate hydrate are added to the solution and, if necessary, pushed with a spatula onto the ground.
4. As soon as the crystal growth is getting slower, the water-glass solution is poured off and the crystals are carefully removed.
5. The crystals are examined with a magnifying glass or under the microscope. In a second step the crystals are carefully broken into pieces and re-examined.

Observation and explanation:

With the microscope, the lump structure of the surface shows that the pressure inside the membrane bulged its surface (Figure 3a). It can also be seen that the crystal strand is hollow inside (Figure 3b). The observation shows a sheath is formed around the metal salt. In the interior of the crystal water diffuses to the already existing metal salt solution, whereby the visible bulges arise. The water accumulates, the osmotic pressure raises until the membrane breaks. This process repeats itself over and over again, so that the growth process can be observed from the outside.

Figure 3a: Surface of the silicate crystal made by copper (II) sulfate

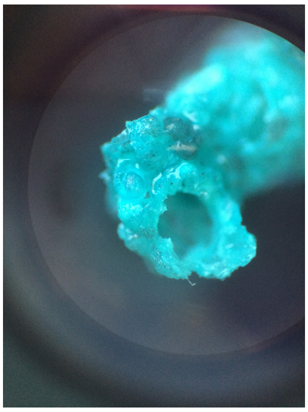

Figure 3b: Hollow space inside the silicate crystal made by copper (II) sulfate

The behaviour of calcium chloride di-hydrate in coloured water glass

Materials/chemicals: calcium chloride di-hydrate, sodium silicate solution (water glass), blue ink, water, glass rod, measuring cylinder, tweezers, plastic cup (0.02 L), spatula, magnifying glass, microscope

Procedure:

1. Mix 10 mL of water glass and 5 mL of water (or other volumes in the ratio 2:1). Add a few drops of blue ink. Stir with a glass rod. Fill a small plastic beaker with the water glass.
2. Add calcium chloride di-hydrate so that a lump is formed at the bottom of the plastic beaker.
3. Wait for a few minutes and observe how the crystals form.
4. After a while, pour out the water glass and remove the crystals.
5. The crystals are examined with a magnifying glass or under the microscope. In a second step the crystals are carefully broken into pieces and re-examined.

Observation and explanation:

When the crystal is removed from the solution it is colored by the blue ink. If the crystal is gently broken up with a spatula we can see that the original calcium chloride lump was coated by the silicate membrane (Figure 4a).

Figure 4a: Ink coloured crystal

The silicate shell encases the calcium chloride di-hydrate crystals (Figure 4a) which are still there as a lump inside the silicate shell. In between the crystal and the shell is a colourless liquid (Figure 4b). The calcium chloride di-hydrate crystals are preserved in their natural colour, as the ink cannot permeate the membrane (Fig. 4b). The silicate shell is, however, blue-purple coloured from the ink (Figure 4c).

Figure 4b: The colourless lump

Figure 4c: The coloured silicate shell

We can recognize that the metal-silicate membrane was permeated by the ink-coloured water. The ink stays in and at the surface of the metal-silicate membrane, which is why the solution is not coloured blue inside. The clear liquid that has been absorbed by the paper in Figure 4a only consists of the metal salt solution.

A demonstration of osmotic pressure

Materials/chemicals: syrup, water, cellophane, film canister or any other water-proof plastic container with a lid, beaker, pierced plug, straw (in case a seal is needed, glue or modelling clay)

Procedure:

1. In the lid of a film canister (or a similar plastic box), a hole is cut. The locking ring must remain intact.
2. A piece of cellophane is softened (about 5 min.) and then fastened with the lock ring on the film canister.
3. In the bottom of the film canister, a hole is drilled so that a straw fits into it to be fixed with a pierced plug.

4. The film canister is placed on the lid and filled with syrup.
5. The straw is plugged with the pierced plug in the hole at the bottom of the film canister to the syrup in the straw rises.
6. If gaps between the plug and the film occur, they are sealed with glue or modeling clay.
7. This construction is placed in a beaker with water so that under the container no air is enclosed.

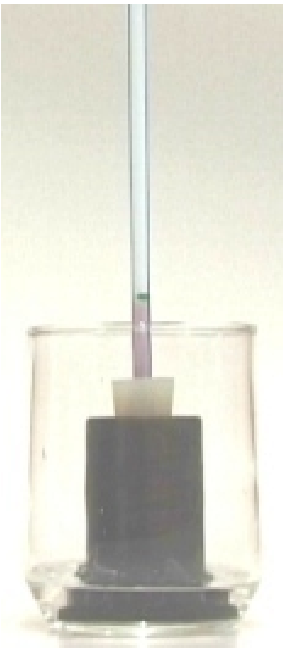

Figure 5: A demonstration of osmotic pressure

Observation and explanation:
After a few minutes, a continuous increase of the syrup level in the straw is revealed. Syrup is a concentrated sugar solution. Outside the film canister is water. As the cellophane is a semi-permeable membrane, the water flows inside the film canister to decrease the concentration gradient. The sugar particles, however, cannot leave the container via the cellophane membrane. Osmotic pressure builds up inside the container, and the syrup rises in the straw.

Conclusion

This paper describes a few easy hands-on experiments to explore and inquire into selected aspects of the phenomenon of the chemical garden. Using open inquiry learning there are many opportunities for further investigations. Various metal salts can be compared for their behaviour in water glass; their different behaviour with respect to temperature, concentration or degree of crystal fragmentation can be tested out to produce the most beautiful chemical garden. Further examples for diffusion, osmosis, osmotic pressure or the behavior of semi-permeable membranes can be added. Many opportunities exist for guided to open inquiry-based learning using this fascinating phenomenon, which may constitute an asset for chemistry lessons not only from an aesthetic point of view.

The work presented here is part of the project *TEMI - Teaching Enquiry with Mysteries Incorporated*. We thank the European Union for funding this project in the 7th Framework Programme Science-in-Society under Grant Agreement No. 321403.

References

Cartwright, J. H. E., Garcia-Ruiz, J. M., Novella, M. L., & Otalora, F. (2002). Formation of chemical gardens. *Journal of Colloid and Interface Science*, 256, 351–359.
Hermenstine, A. M. (2015). Make your own magic rocks. http://chemistry.about.com/od/growingcrystals/a/aa060704a.htm
Hoover, B. (2011). Making a crystal garden. http://www.rsc.org/learn-chemistry/wiki/index.php?title=TeacherExpt:Making_a_crystal_garden&oldid=21126.
Roesky, H. W., & Möckel, K. (1996). *Chemical curiosities*. Weinheim: VCH.
TEMI-Consortium (2015). *Teaching the TEMI way*. London: TEMI-Project. [Online] http://teachingmysteries.eu/wp-content/themes/temi/pdf/Temi_teaching_guidebook.pdf Accessed 30/7/15

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The Instrument Makers No. 8:

Ernst Wilhelm Büchner 8/3/1850 – 25/4/1925

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Ernst Wilhelm Büchner

Ernst's father was Wilhelm Ludwig Büchner (2-Jul-1817 – 14-June-1892), who married his cousin Elisabeth Wilhelimina Frederika Büchner (26/Nov/1821 – 6/May/1908), who came from the Netherlands. Two of his uncles were the controversial playwright Karl Georg Büchner and the philosopher, physiologist and physician Ludwig Büchner. Ernst was the third of three children, all born in Pfungstadt in Germany. His older sisters were Caroline Magdelene Wilhelmine (22/3/1846 – 21/05/1918), Elisabeth Wilhelmine Jeanette (18/01/1848 – 11/10/1848) and Ernst himself was born 8/3/1850.

In 1841 Ernst's father Wilhelm set up a small chemical factory in his father's garden and began experimenting with artificial colorants. Perhaps his greatest achievement was the simplifying the production of ultramarine, a deep blue pigment. In 1845 Wilhelm moved production to the site of the Madder factory in Pfungstadt. His marriage to his cousin brought in a very considerable dowry, which he invested in his company. Profits from the company were good and Wilhelm bought an estate and moved into national politics, supporting the controversial liberal causes taken up by his older brother Karl Georg. In 1882 Wilhelm passed over the management of the company to Ernst but the advent of the aniline dyes cut deeply into the sales of aquamarine and the other natural dyestuffs being produced in the factory, and the company went bankrupt and was closed in 1893.

Father and son 1865

Feeling that the two older girls were having an effeminate effect on the young Ernst Wilhelm, Wilhelm sent him to board at the Weinheim Bender'sche Institute, some thirty kilometres away in 1859. This was a significant reform school, founded in 1829 by Helene Eggert, a pioneer in progressive education. Ernst remained here until 1866 when he moved to the Louis Ochs school in Gernsheim. He spent August and September of 1868 on a prolonged visit to England after which he produced his first publication – a detailed account of his overseas travel.

Ernst now went to study with Wilhelm Rudolph Fittig (6/Nov/1835 – 19/Nov/1910) in Tübingen. This is the Fittig of the Wurtz-Fittig reaction, which can be exemplified by the following scheme:

$C_6H_5.Br + CH_3Br + 2\ Na \rightarrow C_6H_5CH_3 + 3NaBr$

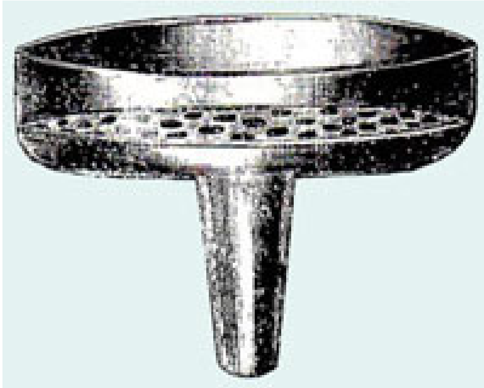
While he was here in Tübingen, Ernst produced a study on ultramarine ($Na_{8-10}Al_6Si_6O_{24}S_{2-4}$) in 1874 and another on the decomposition of bromoaniline (NH_2-C_6H_4-Br) in 1875.

As already mentioned Ernst took control of his father's company in 1882 where he did considerable laboratory work, producing a paper on red and yellow ultramarine and devising his famous funnel and flask in 1885, the patent of which was taken out three years later.

In spite of his work on aniline chemistry, Ernst did not develop the business in this direction and so fell behind the other chemical works. The company went into decline and closed in 1893 leaving Ernst without a job.

Ernst copied his father and married his Dutch cousin Mathilda Büchner (6/Jan/1852 – 1/April/1908) on May 4th 1876. They had two children, Carl (1877 – 1929) and Friedrich Wilhelm (1877 – 1929). The marriage did not last and Mathilda left Ernst taking the two children with her. Ernst married again, this time to Marie Ludovika Karoline von Ferber (08/06/1850 – 20/04/1925) in Berlin on April 2nd , 1885. They had one son, Anton, born in 1887, and dying on 12/08/1954.

The preparation of natural dyestuffs involves considerable filtering, which was painstaking and tedious at the time and many scientists worked at providing apparatus which would lessen the filtering burden. Ernst turned his attention to the problem and in 1885 he designed the now ubiquitious Büchner flask and funnel. The Patents for these were published in 1888. This design, with holes in the flat bottom of the funnel, covered with a circular filter paper, allows a reduced pressure to be applied, thus forcing liquid through the filter paper and speeding up filtration.



The original funnel of Büchner had lower sides than that of the present day one.

Typical present day Büchner flask and funnel. Note the depth of the side of the funnel.

While using the Büchner funnel for filtration, one needs to be careful of the amount of solvent being used. If this exceeds the capacity of the flask the excess will pass on to the vacuum unit attached. In the case of a water vacuum from a tap no harm is caused but if an oil-filled vacuum generator is being used the excess liquid will seriously contaminate the oil reserve of the unit. This can be avoided by putting a trap in the vacuum line.

In the years following the closure of the chemical works in 1893, Ernst got involved with a number of projects including coal gasification and photography. He also pestered the Darmstadt town council with a number of outlandish ideas but was ignored completely. His reserves of money trickled away until he was left destitute.

On the death of his second wife Marie in 1925, Ernst could take no more and five days later took his own life. The couple are buried near to his Aunt Louise (12/Jun/1821 – 28/Nov/1877) rather than with his parents.

References

http://www.rsc.org/chemistryworld/Issues/2009/November/BuchnersFunnel.asp

http://de.wikipedia.org/wiki/Wilhelm_B%C3%BCchner

http://geschwisterbuechner.de/2010/01/12/%E2%80%9Echemistry-world%E2%80%9D-uber-ernst-buchner/

http://gw.geneanet.org/hoffman?lang=de&p=ernst+wilhelm&n=buchner

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If this series by Adrian Ryder has interested you in the history of chemical apparatus, then you may be interested in the series of articles by Andrea Sella, which appear monthly in *Chemistry World*, the RSCs news magazine. These columns are available online at: http://www.rsc.org/chemistryworld/more/?type=opinion-classic-kit

Schrödinger on science education

[A]s you know, scientific education is fabulously neglected … This is an evil that is inherited, passed on from generation to generation. The majority of educated persons are not interested in science, and are not aware that scientific knowledge forms part of the idealistic background of human life. Many believe—in their complete ignorance of what science really is—that it has mainly the ancillary task of inventing new machinery, or helping to invent it, for improving our conditions of life. They are prepared to leave this task to the specialists, as they leave the repairing of their pipes to the plumber. If persons with this outlook decide upon the curriculum of our children, the result is necessarily such as I have just described it.

Erwin Schrödinger

Opening remarks of the second of four public lectures for the Dublin Institute for Advanced Studies at University College, Dublin (Feb 1950), The Practical Achievements of Science Tending to Obliterate its True Import', collected in *Science and Humanism: Physics in Our Time* (1951). Reprinted in *'Nature and the Greeks' and 'Science and Humanism'* (1996), 113.

Exploring the Bernal Project at the University of Limerick

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Building on Key Strengths

It is July 2015 and the University of Limerick's (UL) newly constructed innovative science and engineering building is finally ready. Named in honour of the US-headquartered semiconductor company, Analog Devices (ADI), this building is going to be a hub of scientific and engineering research activity that aims to generate world-class results, stimulate start-ups and enhance existing enterprises, at the University of Limerick.

The University of Limerick (UL) already has a proud track record of excellence and impact in science and engineering research. Building on its key strengths, UL has prioritised key areas, such as manufacturing, process engineering and advanced materials, to address Ireland's academic and research needs. The Bernal Project has been devised to address these key areas, by expanding and enhancing the breath of technical capability and expertise of UL's research community.

What exactly is the Bernal Project?

The Bernal Project is a €56 million strategic investment, to enlarge research excellence at the University of Limerick. It has been funded on a partnership basis between the Irish State, the University of Limerick and philanthropic support. The Atlantic Philanthropies group has been the project's main sponsor to date with a commitment of €26.3 million. Atlantic Philanthropies, together with Analog Devices, embraced this project on recognising that their support could have a major positive impact in advancing a key sector both for the University and for the country as a whole.

This project is an investment to increase research expertise and capacity in Applied Sciences & Engineering, through the provision of state-of-the art laboratory facilities (Analog Devices Building), together with the creation of new Professorship positions (Bernal Chairs), in order to build a multi-disciplinary team of world-leading scientists and engineers at the University of Limerick.

Inspiring Innovation

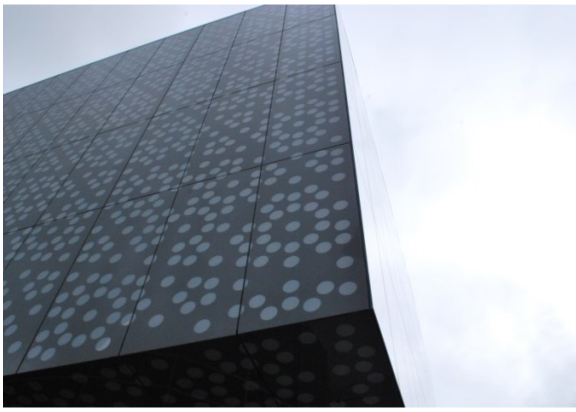
The Analog Devices building was completed in June 2015. Named in honour of US-headquartered semiconductor company, Analog Devices (ADI), following a major gift of €2million by the company to the UL Foundation, this 7500 m^2 building comprises of 10 custom-built, state-of-the art laboratory suites. Located on the South campus, adjacent to existing science and engineering facilities, this new construction will expand and enhance the breath of technical capability and expertise of UL's research community.

At the occasion of the naming of the building Vince Roche, President and Chief Executive Officer of ADI said: *"Analog Devices and the University of Limerick have maintained a strong partnership for decades. This building is a beacon that will shine for many years to come, representing our shared enthusiasm for STEM and commitment to educating future generations".*

UL President Professor Don Barry added*: "The University has a long standing relationship with Analog Devices and we are delighted that the company has chosen to further cement this relationship by naming the new science and engineering building on campus".*
Approximately 150 construction jobs have been created in the construction of the new building, with a further 75 long-term, sustainable research and teaching positions, amounting to a total of 225 jobs being created by the Bernal Project. David Cronin, Chief Executive of the UL Foundation, said: *"As the work that is carried out in the Analog Devices building will significantly support Ireland's national research priorities and contribute to the economic development of the country, it is an excellent fit with a world technological leader like Analog Devices".*

Innovative in Design, innovative in creation

In addition to this significant laboratory space, the building will also provide offices and teaching facilities, including seminar rooms and a 200-seater lecture hall. Innovation has been ingrained, too, into the design and function of the building, with the building reaching an excellent rating on the Building Research Establishment Energy Assessment Method (BREEAM).



Two views of the Penrose tiling pattern on the Analog Devices Building

The **Penrose tiling,** which has been used on the cube feature of the building, was another carefully thought-out decision. Up close these panels may look like randomly distributed spots, but when viewed from a distance a pattern emerges. The pattern is non-periodic (lacks any translational symmetry) and is self-similar, so that the same patterns occur at larger and larger scales. Ordinarily crystal structures are limited to rotational symmetries of 2-fold, 3-fold, 4-fold and 6-fold. Quasicrystals however, can occur with other diffraction pattern symmetries, such as the 5-fold symmetry that has been used in the design of the Penrose tiling. This cladding is a realistic model for the growth of quasi-crystals and will produce Bragg diffraction, whereby its diffractogram reveals both the fivefold symmetry and the underlying long range order. Quasicrystals are a recently new material, discovered in 1982 by Prof. Dan Shechtman, who later was awarded the Nobel Prize in Chemistry in 2011 for this discovery. When viewing the building though it, you can judge how beautiful this chemistry inspired design really is!

The Bernal Professors

The Bernal Project is a tremendous asset to the University of Limerick and has enabled UL to attract scientists and engineers of the highest calibre from the international community to Limerick. Each Bernal Professor, a leading researcher and scholar of their field, will deliver excellence in research to firmly establish UL's reputation as an internationally recognised research-led University.
Undergraduate student, as well as existing departments and research centres, will also benefit from the wisdom and experience of these Bernal Professors through teaching and project work.

Who are the Bernal Chairs?

Currently six Professorial posts have been appointed in the areas of Crystal Engineering (a world first for UL), Pharmaceutical Powder Engineering, Energy, Biomedical Engineering, Microscopy and Imaging, and Fluid Mechanics. The Bernal Professors come from across the globe and together will actively raise UL's international profile, and bringing global recognition of excellent research to Ireland. The six Bernal Professors currently in place are portrayed below.

Professor Gavin Walker

Professor Gavin Walker, who retains a Visiting Research Professorship at Queen's University Belfast, took up the Bernal Chair in Pharmaceutical Powder Engineering in July 2012. Since that time Professor Walker has led and been awarded numerous research grants and is a lead Principal Investigator in the SFI funded Synthesis and Solid State Pharmaceutical Centre (SSPC). This proposal was one of seven SFI Research centre awards announced by Mr Richard Bruton, Minister for Enterprise and Employment on February 25th, 2013. This award represents significant external validation of the Bernal project, with its emphasis on developing UL's capabilities in the area of Pharmaceutical Science and Engineering. Professor Walker presented his inaugural lecture at the University of Limerick on February 24th 2014.

Professor Bartek Glowacki

Professor Bartek Glowacki came from the Department of Materials Science and Metallurgy at Cambridge University, and took up his post as Bernal Chair in Energy on January 1st 2013. His main research interests are Superconductors, Fuel Cells, Hydrogen, Photocatalysts and Fusion. He has published five book chapters, 17 patents and more than 270 scientific papers, as well as a popular YouTube lecture on superconductivity (77,500 viewings). He has received many awards and honours including the life title of Professor from the President of Poland in recognition of the scope and international impact of his research, and the medal of the Foundation for the Promotion of Industrial Science at the Institute for Industrial Science, University of Tokyo. He is a Board member of the European Energy Research Alliance Joint program 'Basic Science for Energy' and a Member of the World Energy Council. He is an editorial Board Member of the *Journal of Energy Science*. Professor Glowacki's appointment has enabled UL to establish meaningful research links with the Department of Materials Science and Metallurgy at the University of Cambridge. Professor Glowacki presented his inaugural lecture at the University of Limerick on 24th of March 2014.

Professor Michael Zawarotko

The University of Limerick offered Professor Michael Zaworotko (Department of Chemistry, University of South Florida) a Bernal Chair in Crystal Engineering in November 2013. Previously, Professor Zaworotko was Dean of Arts and Science at the University of Winnipeg, Professor of Chemistry and Department Chair at St Mary's and has held research positions at the University of Victoria, University of Alabama and Imperial College, London. He has supervised the work of 15 PhD graduates and mentored 8 post-doctoral fellows and his current research group numbers over 20 PhD students and postdoctoral researchers.
Professor Zaworotko is a prolific publisher of high quality peer reviewed journals. His h-index is 77. He has published over 400 original research articles and these have been cited over 27,000 times. He is among the top 20 most cited chemists in the ISI database, was elected Fellow of the American Association for the Advancement of Science in 2011 and is a reviewer for *Science, Nature, JACS and Angewandte Chemie*.
Professor Zaworokto is in demand as a consultant to several major pharmaceutical companies, many of whom have supported his research. He is a member of the Scientific Advisory Council of

UTEK Corporation and a member of the scientific advisory boards of Thar Pharmaceuticals and of Alkermes, Inc. He holds 6 patents and a further 10 are pending. In 2014, he was appointed as a visiting professor at King Abdullah University of Science and Technology in Saudia Arabia.
Since engaging with the Bernal project Professor Zaworokto has been awarded a Science Foundation Ireland Research Professorship, through a competitive program to support iconic appointments to Irish universities. (More information on Crystal Engineering is given below.)

Professor Harry Van den Akker
Professor Harry Van den Akker, Professor in Transport Phenomena, Delft University of Technology commenced his appointment as Bernal Professor of Fluid Mechanics at the University of Limerick in September 2013. Prior to joining the TU Delft, Professor van den Akker was a research engineer at Shell Research in Amsterdam and has held visiting appointment in Princeton and at Kings College London. He has supervised the work of over 30 PhD students at Delft, mentored 7 assistant professors there and has published over 100 peer reviewed journal articles. He is regarded as a world leader in the fluid dynamics of multiphase mixing and was recently awarded the 2015 BHR Group Lifetime Recognition Award in Mixing, in recognition of his outstanding contribution to the field of mixing science and technology in the process industries throughout his 38 year career. His published work is in the top 20 of articles cited from the major journals in the area including *American Institute of Chemical Engineering Journal* and *Chemical Engineering Research and Development*. Prof Van den Akker comes to UL as world leader in the area of Fluid Mechanics and will contribute to all engineering disciplines with Fluid Mechanics at their core. He is actively involved in the Enterprise Ireland funded Dairy Processing Technology Centre, where he is applying his expertise in Fluid Mechanics to a range of projects. He has also commenced an active collaboration with Aerogen, a manufacturer of nebulisers for clinical applications.

Professor Ursel Bangert
Professor Ursel Bangert took up the post of Bernal Professor of Microscopy and Imaging in January 2014. Professor Bangert obtained her PhD in Physics from the University of Cologne, Germany. She held academic posts at the University of Surrey and UMIST prior to her appointment as Reader in the School of Materials in the University of Manchester in 2004. As a member of the electron optics group there, she took an active part in the running and development of the electron optical facilities, and is also strongly involved with the UK STEM facilities at Liverpool and Daresbury.
She has worked in the general area of electron microscopy for over 20 years. A particular interest is the advancement and exploration of electron microscopies combined with spectroscopies with ultra-high spatial resolution. Her research has centred on functional materials, and, more recently, nanostructured materials, the underlying theme being the relationship between micro- and electronic structure. She has pioneered low loss Electron Energy Loss Spectroscopy (EELS) for highly spatially resolved electronic structure studies as well as single atom EELS.
Having worked on electron microscopy of graphene since its discovery at the University of Manchester. (The Nobel Prize in Physics for 2010 was awarded to Andre Geim and Konstantin Novoselov at the University of Manchester for their work on graphene), Professor Bangert was the first to conduct atomic resolution high-angle annular dark-field imaging (HAADF) and low loss EELS on graphene. Recent advances in electron microscopy enable direct visualization of sites of individual atoms in materials as well as revealing their chemical nature. A new generation aberration-corrected (scanning) transmission electron microscopes available to Professor Bangert at the superSTEM facility at Daresbury, UK, where she is a co-grant holder, has enabled her to combine atomic resolution imaging with electron energy loss spectroscopy and DFT modelling to reveal the constellation and chemical nature of point defects, lattice impurities and ad-atoms in graphene. This enabled her to investigate issues that are vital for graphene device applications, such as the metal-graphene interaction (including metal mediated etching: drilling and filling), lattice doping via ion implantation, and graphene plasmon behaviour and enhancement at defects and impurity atoms. Professor Bangert has published over 150 peer review articles including two full papers in *Nature*.
As part of the Bernal Project, the University has purchased a state of the art electron microscope which will be installed in the new building. The

instrument, funded by SFI and by the Bernal project, together with the existing microscopy infrastructure at the University will enable Professor Bangert to establish a world leading electron microscopy centre at the University.

Professor Jacques Huyghe

Professor Jacques Huyghe is to be the incoming Bernal Chair in Biomedical Engineering. Professor Huyghe obtained an M.Sc. in Civil Engineering from the University of Ghent and his PhD in Mechanical Engineering from Eindhoven University of Technology. Previously, Professor Huyghe held academic posts at the University of Maastricht and at Eindhoven University of Technology. Professor Huyghe is a world-leader in the field of porous media mechanics. He has pioneered the development and application of porous media theories for biological, medical and geoscience applications, publishing over 100 papers. Professor Huyghe has extensive experience of engagement in research with industrial partners, including Procter & Gamble, Philips and Shell. He has received several industry awards, including: the Biomedica prize for the Artificial Intervertebral Disc (2010); P&G Swelling Materials Interpore Award (2013); and KBC innovation award (2013). He is a member of the editorial board of the journals *Biorheology* and *Transport in Porous Media* and for many years served as Associate Editor of the *Journal of Biomechanical Engineering*. Professor Huyghe's current research focuses on the development of the world's first biomimetic artificial intervertebral disk. The aim of this work is to develop a prosthetic device that can be implanted, revolutionising the efficacy of disk replacement. In addition, Professor Huyghe is developing non-invasive diagnostic techniques for assessing disk degeneration in patients. He will continue this work as Bernal Chair in Biomedical Engineering.

Conclusion

These new Bernal Professors are outstanding international researchers and will enhance UL's research profile through increased collaborations within and beyond the University of Limerick to strengthen UL's reputation of research excellence.

Who was "Bernal"?

The project was named for one of Ireland's greatest scientists, John Desmond Bernal. Affectionately referred to as "Sage", J.D. Bernal's pioneering research work in crystallography revolutionised this field, with many of his students (Dorothy Hodgkin and Max Perutz) receiving Nobel prizes for their own research work, which was inspired by Bernal. Professor Bernal had a reputation as a selfless supporter of and mentor to young scientists. The Bernal Project and together with the research community that is to follow, will strive to continue this aspiration to inspire, providing positive career profiles and opportunities in science and engineering graduates and researchers for the global scientific community. (For more information on J.D. Bernal see the following article.)

What's next for the Bernal project?

The Bernal Project is a significant part of the UL Capital Development Plan and in time, these 10 Bernal Professors together with their research teams, will fill this fantastic new state-of-the-art laboratory facility with an intense level of research activity, bringing not only an new level of excitement to the University of Limerick but will also be a significant factor for helping the creation new high-value jobs, as well as protecting existing employment to deliver positive impact for Ireland. To find out more about the project's progress as well as opportunities in science & engineering, keep watching our website http://scieng.ul.ie/bernal-project for updates.

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Dr. Sarah Brady is the Executive Administrator for the Bernal project at the University of Limerick, and is currently coordinating activities within the newly constructed Analog Devices Building. Following her PhD in chemistry in 2006, Sarah worked as part of the European multi-disciplinary ProTex project (FP6) before joining the CASTeL science education research team at DCU as research officer. During her work with CASTeL, Sarah was project manager of the EU FP7-funded project ESTABLISH (http://establish-fp7.eu/) as well as member of the coordinating team on the FP7 SAILS (http://www.sails-project.eu/portal) project.

Crystal Engineering Research at UL

Professor Michael Zaworotko

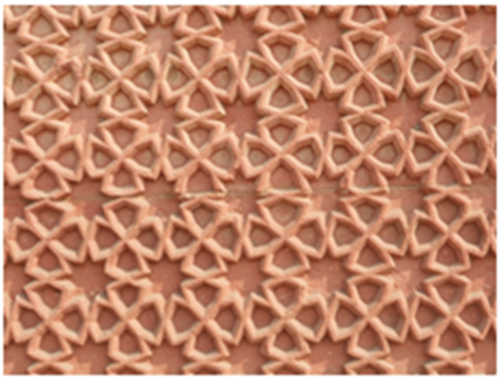
Professor Michael Zaworotko, Bernal Chair of Crystal Engineering at the University of Limerick has been ranked among the world's top 1% highly cited researchers displaying exceptional impact. Only three thousand researchers earned the distinction by writing the greatest numbers of reports officially designated by Essential Science Indicators℠ as Highly Cited Papers—ranking among the top 1% most cited for their subject field and year of publication.

Bernal Chair of Crystal Engineering, Professor Zaworotko is among the top 20 research chemists in the world. Professor Zaworotko also recently secured the first award under the re-launched Science Foundation Ireland (SFI) Research Professor programme.

Professor Zaworokto is in demand as a consultant to several major pharmaceutical companies many of whom have supported his research. He is a Member of UTEK Corporation's Scientific Advisory Council, Member of Thar Pharmaceuticals Scientific Advisory Board and a Member of Alkermes Scientific Advisory Board. He holds six patents and a further 10 are pending.

Professor Zaworotko joined UL as part of the Bernal Project, a €52 million initiative to enhance Science and Engineering which involves the recruitment of 10 world leading professors, a start-up seed fund to support their teaching and research activity and the construction of a new advanced research building on campus. The Bernal Project' will make a significant contribution to Ireland's national research initiatives in the strategically important areas of Pharmaceutical, Biomedical and Energy Research and Development. Named after influential 20th century Irish scientist, John Desmond Bernal who was regarded as the founding father of molecular biology, the project outlines a detailed plan to enhance research excellence in the fields of pharmaceutical science and engineering; energy and sustainable environment; modern and biomedical materials and engineering. Find out more about The Bernal Project. (http://scieng.ul.ie/bernal-project/)

THE VISION: MATERIALS BY DESIGN



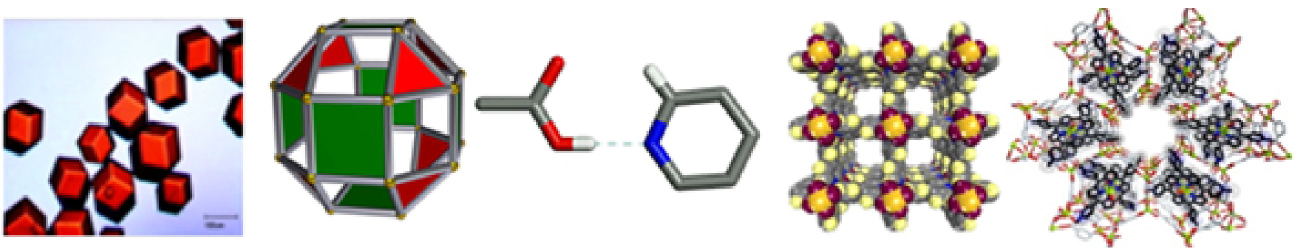
Centuries ago, the Renaissance witnessed the development of new design concepts and the importation of new engineering techniques that revolutionized architecture and enabled the construction of buildings unlike any predecessors. Today we are at a point in time when the expansion of computational power, the development of better/faster characterization methods and the evolution of synthesis concepts such as self-assembly and supramolecular chemistry have enabled the dream of materials by design to approach fruition. This “materials design revolution” is poised to profoundly influence society by impacting, amongst other matters, energy sustainability and drug development. Simply put, by finding the right chemistry, materials scientists and engineers can gain the level of power that architects have when they design new buildings.

THE MEANS: CRYSTAL ENGINEERING

The study of how molecular structure influences crystal structure and physicochemical properties is called crystal engineering. 25 years ago crystal engineering was generally regarded as an oxymoron. Today it has evolved to an extent that materials chemists can serve as architects for de novo design of novel families of compound or platforms. The key to successful crystal engineering is understanding that arrangements of molecules or ions can be controlled via treating them as molecular building blocks (MBBs) that engage in self-assembly. In short, one applies the same concepts of molecular recognition that are exploited by biological systems to materials design. Crystal engineering therefore represents a paradigm shift from the more random, high-throughput approach that has traditionally been used in materials discovery and development.

THE OUTCOME: NEW BENCHMARKS FOR PROPERTIES AND NEW DESIGN PRINCIPLES

Materials platforms that are custom-designed to suit tasks as diverse as drug delivery, carbon capture, natural gas storage, heterogeneous catalysis and commodity purification are at hand. This is because each of these challenges can be addressed with novel materials that overcome weaknesses or handicaps of current technologies. Crystal engineering has recently afforded breakthroughs in both materials design and properties. For example, functional porous materials called **metal-organic materials (MOMs)** with unprecedented surface area (i.e. a football field per gram) can reduce energy consumption by catalysis, carbon capture or natural gas storage and **multi-component pharmaceutical materials (MPMs)** enable the development of new and improved medicines.



J D Bernal – the sage of Nenagh

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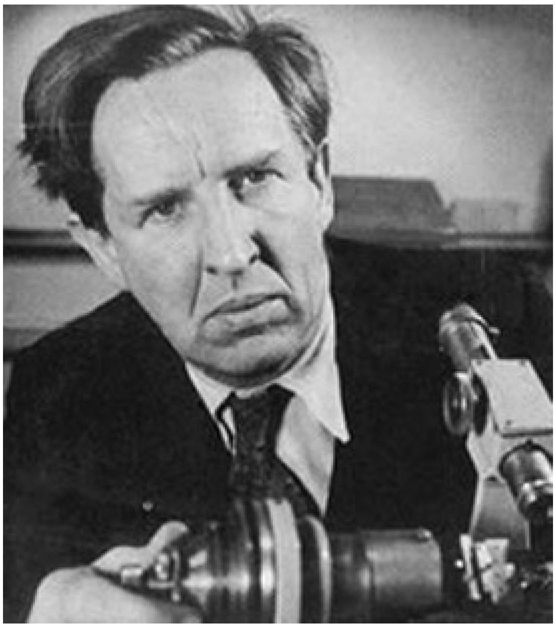


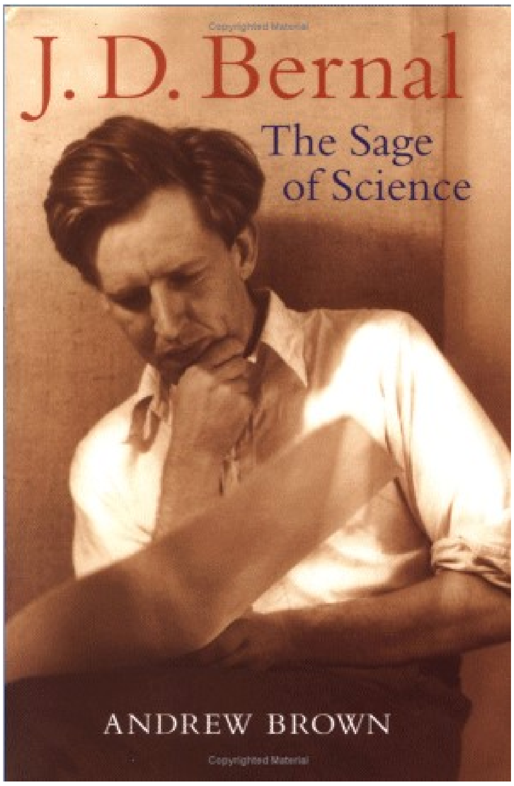
"John Desmond Bernal" by Source. Licensed under Fair use via Wikipedia - http://en.wikipedia.org/wiki/File:John_Desmond_Bernal.jpg#/media/File:John_Desmond_Bernal.jpg
(b. 10 May 1901, Nenagh, Co. Tipperary, Ireland, d. London, 15 September 1971)

As part of the Bernal Project, the new science institute at the University of Limerick, whose Analog Devices Building opened in April 2015, will be named the Bernal Institute after James Desmond Bernal (1901-1971), who was born in Nenagh. Bernal spent his academic career in England, where he was one of the founding fathers of X-ray crystallography, and especially of structural biology. He mentored many other famous scientists, including Nobel laureates Dorothy Hodgkin and Max Perutz, and worked with Kathleen Lonsdale, the Irish-born crystallographer. (Another science building at the University of Limerick is named the Lonsdale Building in her honour.) Bernal was well-known as a polymath, and a prolific reader, who in addition to his scientific work also wrote an influential 4-volume popular work on *Science in History* (1954, Pelican edition 1969). Although he made many important scientific contributions, he was overshadowed by his many students, several of whom went on to win Nobel prizes, but his influence and inspiration played a large part in their success.

Maurice Goldsmith wrote:
"His strength lay in causing other minds to light up. Most of the leading names in Britain working on molecular biology and the analysis of Protein crystals were either Bernal's associates or students. Wherever he went he left behind intellectual 'fall out', providing more than sufficient for a lifetime of scientific work. If one traced back almost any fruitful line of crystallographic work it would be found that Bernal assisted at its conception, but, significantly, left the child to be brought up by foster-parents."

Brought up a fervent Catholic as a child, he became an ardent Marxist as an undergraduate in Cambridge. This influenced his view of history and the role of science, and he supported communist Russia, even after Stalin's excesses became known. In addition he was known as a womaniser and his personal life was complex, to say the least. His political and social views did not endear him to the establishment.

Dorothy M. C. Hodgkin (a former student who had a relationship with Bernal), wrote in her biography for the Royal Society:
"John Desmond Bernal lived his life to the full. He liked to say that his biography ought to be written in four colours, on interleaved pages, to show his different activities, fitted together. Oral tradition differs as to the colours of the pages; black and white, certainly for science, red for politics, blue for arts, purple or yellow for his personal life"
Biogr. Mems Fell. R. Soc. 1980 26 16-84; DOI: 10.1098/rsbm.1980.0002. Published 1 November 1980
http://rsbm.royalsocietypublishing.org/content/roybiogmem/26/16.full.pdf



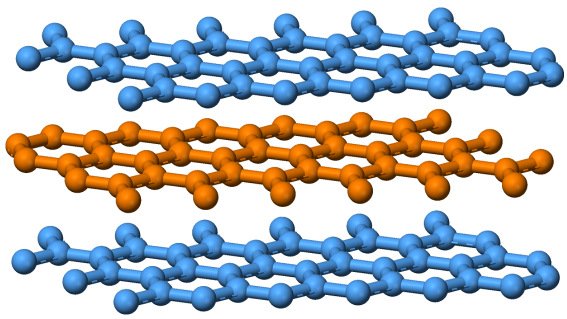
In 2007 Vincent Casey, from the Physics Department at UL, organised a conference in Limerick Institute of Technology on the life and work of J. D. Bernal, and the Proceedings were published in the *Journal of Physics: Conference Series* **57** (2007) 61–72, on 'John Desmond Bernal: Science and Society'. (http://iopscience.iop.org/1742-6596/57/1) You can read the introductory article by Bernal's biographer, Andrew Brown, at: http://iopscience.iop.org/1742-6596/57/1/006/pdf/jpconf7_57_006.pdf, who has also produced a biography of Bernal (see cover above).

Outline of his career

He was born in Nenagh, Co. Tipperary on May 10th 1901. He was originally educated in Nenagh but in 1910 his parents sent him to England to be educated and most of his secondary education was at Bedford School, Bedford. From there he went in 1919 to Emmanuel College, Cambridge on a scholarship. He was a distinguished student and graduated in 1922 in mathematics and physics. Based on his work for an undergraduate essay on the 230 space groups in 1923, he was invited to work with Sir William Bragg at the Royal Institution, London in the relatively new field of crystallography. There he worked on the structure of graphite and bronze, did work on how to analyse diffraction photographs, developed a spectrogoniometer, and started work on biological materials. He was the first to show conclusively in 1924 the hexagonal structure of graphite, now known as Bernal stacking (see below). This structure is important in understating the structure and properties of graphene, a single sheet of graphite. In 1934 he and Dorothy Hodgkin obtained the first X-ray diffraction pattern for a protein, pepsin. Having shown it was possible Bernal left it to others to solve the structure of proteins.

Sir Lawrence Bragg said of Bernal: "if one traces back almost any fruitful line of crystallographic work, it will be found that Bernal *assisted at its conception but left the child to be brought up by foster-parents. This is particularly so in the case of molecular biology and in the analysis of protein crystals. Immediately on seeing the first x-ray differentiation pictures from protein crystals...he assumed that protein structures would sooner or later be solved, and handed out problems to his students and to anyone whom he could persuade to take them up."*

Bernal and his group also produced the first X-ray patterns for viruses in the late 1930s, which would later lead to a determination of their structures.



"Graphite-layers-side-3D-balls" by Benjah-bmm27 - Own work. Licensed under Public Domain via Commons - https://commons.wikimedia.org/wiki/File:Graphite-layers-side-3D-balls.png#/media/File:Graphite-layers-side-3D-balls.png

In 1927 he went back to Cambridge as Lecturer in Structural Crystallography. He was turned down for college fellowships and a professorship in Cambridge, and Sir Ernest Rutherford reputedly did not like him. In 1934 he became Assistant Director of the Cavendish Laboratory and in 1937 moved to Birkbeck College, University of London as Professor of Physics until 1963, when he was appointed Professor of Crystallography at Birkbeck. He was made an FRS in 1937 and during WWII he was a scientific adviser and developed operational research. In 1948 he set up the influential Biomolecular Research Laboratory at Birkbeck. He remained at Birkbeck for the rest of his academic career (apart from the war years).

He is seen as the father of structural biology and was the first to show that crystalline proteins would give diffraction patterns and developed methods to obtain them using X-rays. He was the academic father directly or indirectly of five Nobel laureates in crystallography: Dorothy Hodgkin, Aaron Klug, Max Perutz, Maurice Wilkins and John Kendrew. Many scientists thought that Bernal should have won a Nobel Prize for the structures of the sex hormones. (The article by Martin Caffrey, referred to below, gives an excellent introduction to protein crystallography.) He did important work at the end of his career on the structure of water and other liquids. His Bakerian Lecture in 1962 for the Royal Society was on 'The structure of liquids.' (http://www.physics.emory.edu/faculty/weeks//lab/papers/bernal-best64.pdf)

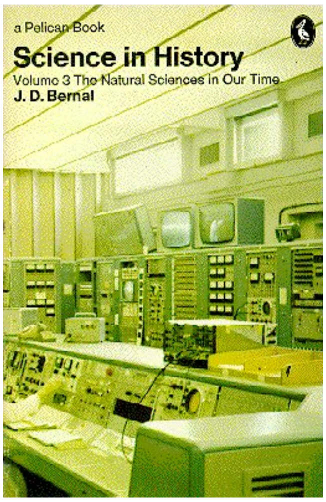
Bernal did important work in many areas, mainly in crystallography. He published 224 papers, nearly 400 articles and several books. As well as opening up the field of structural biology, he also made important contributions to operational research, information science and the social history of science.

"I remember excitedly buying a boxed set of 4 books, Science in History by John D. Bernal (Pelican, 1965), when I was an undergraduate. At the time I was an amateur Marxist and Bernal's work was an encyclopaedic analysis of science and society from a Marxist point of view. I was delighted to learn that Bernal was an Irishman who had spent a brilliant career at the leading edge of UK science, making many notable contributions "

William Reville

He married Eileen Sprague 2 days after graduation and they had two children: Michael and Egan. They had an open marriage and he also had children with Margaret Gardiner (Martin) and with Margot Heinemann (Susanna). He lived and worked in London from 1937 until his death. He died in London after a long illness on Sept. 15th. 1971.

Publications

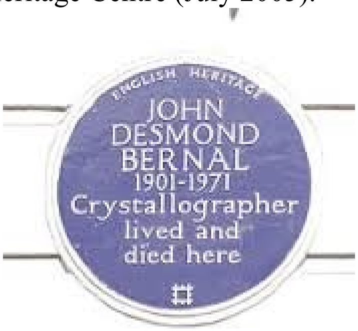


Bernal wrote a number of influential popular science books including:

1929 *The world, the flesh and the devil*
1939 *The social function of science*
1954 *Science in History* (4 volumes)
1967 *The origin of life*

Awards

Plaques in his honour have been located at 44 Albert Street, London NW1 in March 2001, the house where he lived and died in 1971,and in the Nenagh Heritage Centre (July 2005).



In his life he won many awards: The Royal Medal of the Royal Society (1945), the US Medal of Honour (1945) and the Lenin Peace Prize (1953).

Some views on Bernal:

Herbert Butterfield (historian) said:

"Bernal was a big man of captivating charm who certainly influenced hundreds of undergraduates. He was that rare creature, a person of truly seminal ideas on a host of subjects, yet one who would never have exercised the cumulative

persistence with detail required to win a Nobel Prize. I liked Bernal enormously."

Christopher Freeman wrote:
"The extent of his faith in science can best be described as religious devotion. He comments himself: 'The same type of mind that would now make a physicist would in the Middle Ages have made a scholastic theologian."
The economics of hope: essays on technical change, economic growth, and the environment. (1992) p. 25

Martin Caffrey (TCD) wrote:
"Bernal teemed with ideas and his interests were catholic. And he was generous to a fault with these ideas, as noted. He was erudite, articulate and insightful. The range of his knowledge was matched only by its depth. He was after all a very good mathematician and physicist, and an expert crystallographer. Coupled with an unbridled enthusiasm, optimistic outlook and vision meant he attracted the very highest calibre students, staff and associates. As we know many of them went on to win major awards including the Nobel Prize. Bernal was a persuasive, interesting and an engaging controversialist and communicator."
J.D. Bernal and the genesis of structural biology (in the IOP publication, 2007)
http://www.tara.tcd.ie/xmlui/bitstream/handle/2262/50462/J%20D%20Bernal.pdf;jsessionid=17A6F8EE888B4CC20D0C08F248D68EFE?sequence=1

Some quotes from Bernal:

J.D. Bernal *The social function of science* (1939)
"In science men have learned consciously to subordinate themselves to a common purpose without losing the individuality of their achievements. Each one knows that his work depends on that of his predecessors and colleagues, and that it can only reach its fruition through the work of his successors. In science men collaborate not because they are forced to by superior authority or because they blindly follow some chosen leader, but because they realize that only in this willing collaboration can each man find his goal, not orders, but advice, determines action. Each man knows that only by advice, honestly and disinterestedly given, can his work succeed, because such advice expresses as near as may be the inexorable logic of the material world, stubborn fact. Facts cannot be forced to our desires, and freedom comes by admitting this necessity and not by pretending to ignore it. These are things that have been learned painfully and incompletely in the pursuit of science. Only in the wider tasks of humanity will their use be found."

J. D. Bernal *The Social Function of Science* (1939)
"At different stages in the educational process different changes are required. In schools the chief need is for a general change in the attitude towards science, which should be from the beginning an integral part and not a mere addition, often an optional addition, to the curriculum. Science should be taught not merely as a subject but should come into all subjects. Its importance in history and in modern life should be pointed out and illustrated. The old contrast, often amounting to hostility, between scientific and humane subjects need to be broken down and replaced by a scientific humanism. At the same time, the teaching of science proper requires to be humanized. The dry and factual presentation requires to be transformed, not by any appeal to mystical theory, but by emphasizing the living and dramatic character of scientific advance itself. Here the teaching of the history of science, not isolated as at present, but in close relation to general history teaching, would serve to correct the existing atmosphere of scientific dogmatism. It would show at the same time how secure are the conquests of science in the control they give over natural processes and how insecure and provisional, however necessary, are the rational interpretations, the theories and hypotheses put forward at each stage. Past history by itself is not enough, the latest developments of science should not be excluded because they have not yet passed the test of time. It is absolutely necessary to emphasize the fact that science not only has changed but is continually changing, that it is an activity and not merely a body of facts. Throughout, the social implications of science, the powers that it puts into men's hands, the uses they could make of them and those which they in fact do, should be brought out and made real by a reference to immediate experience of ordinary life."
MIT Press paperback ed., March 1967. Routledge, 1946; digitized 2007 p. 246
J.D. Bernal, *The Extension Of Man: A History Of Physics Before 1900*
"In my own field, x-ray crystallography, we used to work out the structure of minerals by various dodges which we never bothered to write down,

we just used them. Then Linus Pauling came along to the laboratory, saw what we were doing and wrote out what we now call Pauling's Rules. We had all been using Pauling's Rules for about three or four years before Pauling told us what the rules were."

J.D. Bernal on his time at the Royal Institution (1923-27):
"These early years at the Royal Institution were certainly the most exciting and the most formative 'of my scientific life. We who had the privilege to be among the first of those 'who worked there were quite exceptionally lucky because we were at a point when a new field, the arrangement of atoms in crystals, was just being worked out. No one will ever have precisely that kind of excitement again now that the. main types of crystal structures are known. Just because we did not know what to expect, every discovery opened up new possibilities."
http://www.iucr.org/__data/assets/pdf_file/0003/759/bernal.pdf

Conclusion:

J.D. Bernal was well named the Sage, for his prolific interests and breadth of knowledge, as well as his appearance. Interestingly was an almost exact contemporary of Kathleen Lonsdale (1903-1971), another Irish-born crystallographer. They were both pioneers in the new scientific field of crystallographer and both worked most of their careers in colleges of the University of London. Bernal's first paper was on the hexagonal structure of graphite, and Lonsdale's was on the hexagonal structure of benzene.

Bernal had an immense influence on many people and in many field of knowledge. So it is fitting that the new Institute at the University of Limerick will be named after him, joining the Lonsdale Building in honouring two important Irish-born crystallographers, bringing together a wide researchers on a wide range of topics in the physical sciences.

This is Dorothy Hodgkin's summary of Bernal in RS Biography (cited below):
*"[Bernal] himself passed on [from metals] and started research in many other fields, more than he could possibly pursue to conclusions himself – though he always enjoyed the mechanics of problem-solving, mathematics, model building, looking down microscopes. His particular qualities, insight, imagination, ingenuity, a feel for structures, are nowhere shown better than in the work on the liquid state on which he spent his own research time in the last ten years of his working life. **But probably his greatest gift was his power to inspire others, his infectious optimism – that as he talked it seemed clear that the structure of proteins could be solved, that peace was possible.***
Lindeström-Lang once said of him 'whenever Bernal comes into my laboratory he makes me feel that everything I am doing is absolutely worthwhile.'"
p. 73 in D. Hodgkin, *Biog Mems.Fell.R.Soc.* (1980) **26** 16-84

Sources:

http://en.wikipedia.org/wiki/John_Desmond_Bernal

http://www.iol.ie/~rjtechne/scihist/brnlwhit.htm

http://garfield.library.upenn.edu/papers/bernaldublin0907.pdf

Dorothy M. C. Hodgkin, *Biogr. Mems Fell. R. Soc.* 1980, **26** ,16-84; DOI: 10.1098/rsbm.1980.0002.
http://rsbm.royalsocietypublishing.org/content/roybiogmem/26/16.full.pdf
Irish Times article by William Reville:
http://undersci.ucc.ie/wp-content/uploads/sites/12/2014/11/John_Desmond_Bernal.pdf
Martin Caffrey, J.D. Bernal and the genesis of structural biology
http://www.tara.tcd.ie/xmlui/bitstream/handle/2262/50462/J%20D%20Bernal.pdf;jsessionid=17A6F8EE888B4CC20D0C08F248D68EFE?sequence=1

Andrew Brown, 2005, *J. D. Bernal: The sage of Science*, Oxford: OUP

□

2014 and 2015 LC Results

Peter E. Childs

We have been publishing an analysis of the LC science results and CAO points for science-related courses since 2001. Each year a 3-4 year overview is given. The examination statistics are available at the Department of Education and Science website at: www.examinations.ie and were published in the Irish newspapers on 13/8/14 and on 12/8/15, the day the LC results were released. (See http://www.education.ie/en/Press-Events/Press-Releases/2014-Press-Releases/PR2014-08-13.html and https://www.examinations.ie/misc-doc/BI-ST-91036610.pdf) This year we are publishing the 2014 and 2015 results together. Due the small numbers doing the Physics and Chemistry course (~1% of the LC cohort), these figures have been omitted this year, especially in the light of the outdated syllabus.

In 2014 the overall number sitting the examinations is marginally up on the 2013 figures by 2.55% and rose again in 2015 by 1.6% (see Table 1). This total figure includes the LC Established (LC (Est)), the LC Vocational Programme (LCVP) and the LC Applied Programme. For the purpose of calculating % uptake of different subjects the figure used is LC (Est) + LCVP. Unless the % increase in raw numbers is greater than the % increase in the LC cohort, there is no real increase in uptake.
Over 90% of JC students now stay on to do the leaving certificate course.

Table 1 shows the change in size and composition of the LC cohort from 2005 to 2015. After a minimum number in 2007, the numbers doing the LC increased above 2005 levels in 2010 and then declined, however, they are due to continue increasing in the foreseeable future due to the increased birth rate working its way up through the schools system. The drop from 2010 is probably due to emigration and will be corrected in future years. In 2015 the number has recovered and exceeded the 2005 figure.

Table 1: Change in LC numbers 2005-2015

Year	LC (Est)	LCVP	Total LC (Est) + LCVP	LCAP	Total
2005	39,792	14,281	54,073	3,318	57,391
2006	36,932	14,023	50,955	3,155	54,110
2007	36,790	14,080	50,870	3,056	53,926
2008	37,639	14,505	52,144	3,445	55,589
2009	39,112	15,084	54,197	3,264	57,455
2010	38,885	15,596	54,479	3,358	57,837
2011	37,995	16,386	54,344	3,195	57,539
2012	36,762	15,827	52,588	3,228	55,816
2013	37,093	15,671	52,767	2,805	55,572
2014	**38,751**	**15,274**	**54,025**	**2,965**	**56,990**
2015	**40,121**	**14,924**	**55,045**	**2,884**	**57,929**

One matter of concern in education at all levels is the future increase in numbers due to an increased birth rate. This year's LC cohort would have been born in 1997/98. The number doing the LC exams is affected by numbers doing TYO, and by the effects of emigration (loss) and immigration (gain). Over half the LC cohort now take the TYO, which delays them by a year doing the LC exams. However, the data in Table 2 shows that the maximum number of births was in 2009 (39.3% increase from 2000). The 2014 figure is 24.4% up on 2000, despite the fall in the number of births. These are large increases and the 2009 bulge is already in primary school. It will hit post-primary schools around 2021 and third level around 2016, but numbers will already have increased before then. This will mean that more schools are needed and more teachers at primary and post-primary level, which is good news for teacher employment and bad news for the Department of Finance.

Table 2: Irish birth rates 2006-2015 (Source: CSO)

Year	No. of births	~Date in post-primary	~Date into LC cohort
2000	54,239	2012	2015
2001	57,854	2013	2016
2002	60,521	2014	2017
2003	61,429	2015	2018
2004	61,972	2016	2019
2005	61,372	2017	2020
2006	64,237	2018	2021
2007	71,389	2019	2022
2008	75,173	2020	2023
2009	75,554	2021	2024
2010	73,724	2022	2025
2011	74,650	2023	2026
2012	~71,986	2024	2027
2013	68,930	2025	2028
2014	67,462	2026	2029

From birth it takes ~12 years to enter post-primary education and another 5/6 years to the LC exams. So the LC class of 2012 would have been born in ~ 1995 when the birth rate was 48,530 and that of 2015 in 1998 when the birth rate was 53,551. We have had a lot of immigration and more recently increased emigration since then, but this figure is in line with the 2012 LC numbers of 55,815 and the 2015 figures of 57,929. The birth rate figures jump around 2001, and from 2009 they have started to decline. The figures indicate an expansion of primary intake from ~2006 until ~2014 and in post-primary intake from ~2014 to 2020, before starting to decline. These data have major implications for schools and third level institutions and more schools, more teachers and more places at third level will needed in the future. Figures from Eurostat in 2014 show that Ireland still has the highest birth rate in the EU – 14.4/1000 compared to the EU average of 10.4/1000.

Table 3: Estimated numbers at primary and post-primary levels 2012-2015 (* projections) Source: ww.education.ie

Year beginning	**First Level**	**Second Level**
2012	524,901	322,528
2013	539,436	337,320
2014	544,696	339,210
2015*	555,134	343,972
2016*	563,093	349,764
2017*	569,562	354,290

N.B. These numbers are aggregated over the total numbers of years in primary and post-primary education.

A recent publication (July 2015) looks at 'PROJECTIONS OF FULL TIME ENROLMENT Primary and Second Level, 2015 – 2033' (available at http://www.education.ie/en/Publications/Statistics/Statistical-Reports/Projections-of-Fuil-Time-Enrolment-Primary-and-Second-Level-2015-2033.pdf) and is updated each year. The projections

are shown in Table 3. These projections change from those made a year earlier and are also probably out-of-date and underestimate the growth in student numbers. In September 2013 ~71,000 students entered primary school.
These figures have massive implications for schools and for third level institutions in the future. More schools, more classrooms, more teachers will needed at primary and post-primary levels to cope with the increase in numbers. The most probably scenario for change would suggest an increase in enrolments at primary level to a maximum of **573,054** by **2018 (**a rise of 9.2% since 2012), and a continuous decline thereafter, and a year-on-year increase in second-level enrolments to a peak of **405,565** over the period considered (occurring in **2025**, an increase of 25.7% since 2012), with a decrease in enrolments occurring from that point. These are estimates and are revised each year. There are also projections for enrolments at third level.

We must take account of the changing examination cohort if we are to make sense or an increase or decrease in numbers doing a subject, as the raw numbers are related to the size of the total cohort. (See below to find out what actually happened to the popularity of science subjects in 2014 and 2015 and which were the winners and losers).

The same is true for the UK A-levels, but there the number of entries rather than number of students is usually published and this makes it impossible to see how popular a subject is compared to the size of the cohort and whether enrolment is going up or not. The raw number of entries alone is not enough as students take different numbers of subjects. I have found it very hard to get hold of the number of A level candidates in the UK (excluding Scotland), though it is ~ 330,000. Knowing the size of the examination cohort and the number of candidates (entries) in a particular subject allows us to compare the popularity of different subjects across different school systems.

Comments on the 2014 and 2015 results

Unless specified otherwise all the statistics are from the SEC or DES websites. Table 3 shows that all the sciences, except Physics and Physics & Chemistry, gained both numbers and % share and Agricultural Science and Chemistry made the largest % gains. Over the period 2002-2015 all the sciences gained numbers except Physics which has shown a steady decline down to 2013. Biology continues to be the dominant LC science subject (taken by 61.5% of the cohort) and the only science subject in the top 10 subjects (Table 9). The LC cohort increased slightly this year by 1.6%, and Biology, Chemistry and Physics all gained in market share (see Tables 4 & 11), but Ag. Science dropped back in 2015. Figure 1 shows the % taking the main science subjects since 1999 i.e. this is normalised for the change in size of the LC cohort.

Table 4: Changes in numbers doing LC Science subjects 2009-2013 (gains in bold)

Subject	**Δ2014 -2015**	**Δ% 2014-15**	**Δ2013 -2014**	**Δ% 2013-14**	**Δ2012 -2013**	**Δ% 2012-13**	**Δ2002-2015 (Δ %)**
Biology	**+909**	**2.75**	+1,456	**+4.6**	**+959**	**+3.1**	**+11,801 (+53.5)**
Chemistry	**+334**	+3.9	**+449**	**+5.5**	**+69**	**+0.85**	**+2,441 (+37.6)**
Physics	**+331**	**+4.6**	**+729**	**+11.3**	**+75**	**+1.2**	-1,143 -(13.2)
Ag. Science	-254	-3.2	**+512**	**+6.9**	**+525**	**+7.6**	**+4,782 (+165.5)**

Since 2002 Biology, Chemistry and Agricultural Science have all gained significantly, especially Biology and Agricultural Science (see Table 3). Physics decreased over this period. In 2013 Chemistry had the highest % doing the Higher Level course of the science subjects (82.8%), closely followed by Agricultural Science, with 80.1% (Table 5). Chemistry also shows the best gender balance (with a small excess of girls), whereas Biology has many more girls than boys doing it, and Physics many more boys than girls (Table 8). Physics has been in decline but is showing some recovery. In 2012 Agricultural Science overtook Physics as the third most popular science. There is clearly a continuing swing towards the life sciences. Physics & Chemistry has been on its last legs for some years and continues to decline - it is definitely a 'dead man walking' of a syllabus, and it is a great pity that the new and innovative replacement, which was drawn up by the NCCA many years ago, has never been implemented. Sadly the new syllabus in Physics & Chemistry is still gathering dust on a shelf in the NCCA – it was a radical and innovative syllabus and it deserved an airing – it could have provided a popular alternative to the full Physics and Chemistry syllabi. If the course is not going to be revised it should be dropped as it must be one of the oldest/longest-lasting science syllabi in the world by now, along with Agricultural Science, both over 40 years old! The Agricultural Science is at last being revised and this may well have an impact on future figures, and may indeed increase its appeal.

Biology is still far and away the most popular science subject, trailed at a distance by Chemistry and Physics: four times as many students take Biology as take Chemistry and Physics. It is clear that the Physics & Chemistry syllabus is dying on its feet, whereas Agricultural Science is growing steadily (+4,782 since 2002). All the sciences are quite elitist, with Chemistry and Agricultural Science (surprisingly) heading the poll with 84.3% and 79.1% respectively, doing the HL course (Table 4). This marked disparity between Biology and the Physical Sciences is more marked in Ireland than it is in most other countries.

Table 5: LC Science - % doing Higher Level and Ordinary Level 2015-2014

	2015 Total number	**HL 2015 (%)**	**OL 2015 (%)**	**%LC Cohort 2015**	**2014 Total number**	**HL 2014 (%)**	**OL 2014 (%)**	**%LC Cohort 2014**
Biology	**33,865**	**75.6**	**24.4**	**61.5**	32,956	74.2	25.8	61.0
Chemistry	**8,938**	**84.3**	**15.7**	**16.2**	8,604	84.0	16.0	15.9
Physics	**7,508**	**75.6**	**24.4**	**13.6**	7,177	75.2	24.8	13.3
Ag. Science	**7,672**	**79.1**	**20.9**	**13.9**	7,926	79.9	20.1	14.7

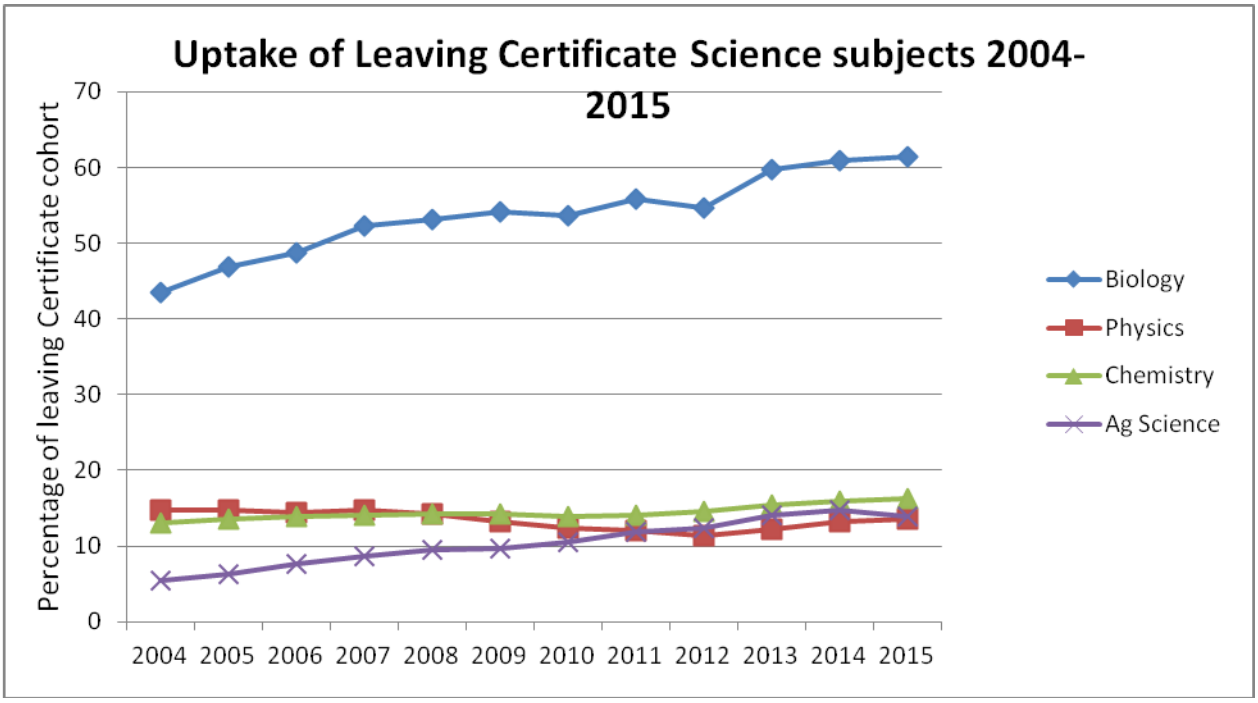


Figure 1: Change in % doing Biology, Physics, Chemistry and Ag. Science 2004-2015

Table 6: % of different grade bands 2015-2010

a)Chemistry

	Higher level						Ordinary level					
Year	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**
%A	**21.9**	20.6	20.4	19.9	21.9	20.8	**6.4**	9.5	7.1	7.6	9.1	7.6
%A+B	**50.3**	49.7	48.2	48.4	52.4	50.1	**27.4**	34.3	28.5	29.7	36.4	29.8
%A+B+C	**73.4**	72.8	73.4	72.5	76.0	75.3	**57.1**	52.9	58.2	59.4	64.7	54.9
%E,F,NG	**8.6**	8.9	8.1	9.0	8.6	6.1	**18.6**	15.6	8.2	16.6	12.8	18.5

b) Biology

	Higher level						Ordinary level					
Year	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**
%A	**16.1**	13.6	14.4	16.7	15.6	17.4	**1.4**	1.6	2.1	1.3	2.2	3.1
%A+B	**47.1**	39.4	41.7	44.4	43.0	44.9	**21.1**	20.4	23.7	17.9	22.8	29.6
%A+B+C	**76.3**	69.4	69.6	71.1	69.9	71.6	**62.8**	59.6	58.5	58.4	59.3	62.7
%E,F,NG	**5.1**	6.8	8.2	8.4	8.3	9.2	**7.9**	9.1	13.4	13.5	13.2	14.1

c) Physics

	Higher level						Ordinary level					
Year	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**	**2015**	**2014**	**2013**	**2012**	**2011**	**2010**
%A	**20.6**	19.8	20.4	19.8	20.2	20.8	**14.4**	14.9	14.5	15.2	14.8	17.4
%A+B	**45.5**	47.8	49.4	49.6	46.0	49.6	**44.6**	41.8	45.8	46.5	44.3	49.0
%A+B+C	**69.2**	72.4	73.3	74.6	72.9	73.3	**73.0**	69.3	72.7	71.8	72.2	72.8
%E,F,NG	**9.5**	8.2	7.2	7.3	8.0	7.0	**8.8**	10.0	9.3	9.7	11.2	11.6

In Table 6 you can compare the grades obtained in each subject at Higher and Ordinary level. Four bands are shown: %As, %A+Bs, %A+B+Cs and %E+F+NG (fails). In 2015 at HL Chemistry (21.9%) and Physics (20.6%) students get more As compared to for Biology (16.1%), although this represents over 3 times more students getting As in Biology. This disparity reflects the larger and academically wider intake into Biology and also probably that Chemistry and Physics attract a greater proportion of higher ability students. These results are fairly consistent over 6 years as can be seen above. At OL the differences are more marked – Physics students get 14.4% As at OL, whereas Chemistry students get 6.4% and Biology students 1.4%. The failure rates at HL for all three main sciences are very similar, as they are at OL, but remember that for Biology these represent greater numbers of students. There is no marked change in the grading over this six year period for any of the three main science subjects. The Physics results suggest that some able Physics students drop down to the OL paper at the last minute.

Chemistry and Physics are more selective subjects i.e. they are done by smaller numbers and a higher % take the Higher Level papers, indicating that these are taken by better students. We would thus expect a higher % of good grades and less % of fails if the student populations doing Chemistry and Physics are more selective. This is what we observe. From 2010-15 the average % getting As in HL papers in Chemistry was 20.9% and 20.3% in Physics, compared to15.6 % in Biology. This does not mean that Biology is harder than Chemistry or Physics: it means that a larger number of students take Biology and have a greater ability spread, compared to Chemistry and Physics. The average % of fails 2010-15 is similar in HL Chemistry of 8.2%, compared to 7.9% in HL Physics and 7.7% in HL Biology. Again remember that the same % in Biology represents nearly 4 times as many students. Chemistry and Physics have a higher proportion of students doing the HL paper than Biology.

At Ordinary Level we would expect to see smaller % of good grades, as weaker students opt for the ordinary level papers - often at the last minute, and a greater % of fails. We would also expect more % fails in Biology than Physics or Chemistry, because of the greater numbers and wider ability spread of students choosing Biology. The average % getting As in ordinary level Chemistry was 7.9% from 2010-15, with 15.2% getting As in Physics and 2.0% in Biology. The anomalies here are the high % of As in Physics and to a lesser extend in Chemistry and the very low % in Biology. When we look at the % fails in the ordinary level papers from 2010-15, 15.1% fail OL Chemistry, 10.6% fail OL Biology and 11.9% fail OL Physics, which are fairly consistent.

Table 7: Gender breakdown of A grades 2015

	%As overall	**%As females**	**% As males**
Chemistry	21.9 (HL) 6.4 (OL)	21.4 (HL) **8.0** (OL)	22.5 (HL) 5.0 (OL)
Biology	16.1 (HL) 1.4 (OL)	**15.5** (HL) **1.6** (OL)	14.6 (HL) 1.3 (OL)
Physics	20.6 (HL) 14.4 (OL)	**20.9** (HL) **20.5** (OL)	20.5 (HL) 13.2 (OL)
Ag. Science	10.9 (HL) 5.5 (OL)	**14.2** (HL) **1.2** (OL)	8.8 (HL) 0.0 (OL)
Maths	10.6 (HL) 5.5 (OL)	7.5 (HL) **5.6** (OL)	13.4 (HL) 5.4 (OL)

Table 7 shows the gender breakdown of the 2015 HL and OL results for A grades. In several cases females outperform males (larger % shown in bold above), although the differences are small and boys get more As in both Chemistry and Physics, whereas girls do better at OL. The trend for females to outperform males in state examinations has become more apparent year on year. We cannot say from these data whether this difference is due to intrinsic ability or to better study methods and harder work or the effect of single-sex schools. The better LC results by females mean that the number of females entering third level exceeds that of males, and more males drop out of fulltime education at all levels.

However, the gender balance in the LC science subjects is still a matter of concern. Table 8 shows the overall gender breakdown of the five science subjects i.e. HL and OL students are combined in these figures and the F:M ratio for each subject from 2011 to 2015.

Table 8: The overall gender balance in the LC Science subjects 2015-2011 HL+OL

Subject	No. Females 2015 (%)	No. Males 2015 (%)	No. Females 2014 (%)	No. Males 2014 (%)	Ratio F:M 2015	Ratio F:M 2014	Ratio F:M 2013	Ratio F:M 2012	Ratio F:M 2011
Biology	**20,438**	**13,427**	19,644	13,313	**1.52:1**	1.48:1	1.45:1	1.54:1	1.60:1
Chemistry	**4,942**	**3,996**	4,364	4,640	**1.24:1**	0.94:1	1.13:1	1.16:1	1.23:1
Physics	**1,875**	**5,633**	2,148	4,629	**0.33:1**	0.46:1	0.31:1	0.33:1	0.33:1
Ag. Science	**2,920**	**4,752**	2,962	4,964	**0.61:1**	0.60:1	0.60:1	0.66:1	0.59:1
Mathematics	**24,313**	**23,644**	23,227	23,526	**1.03:1**	0.99:1			

As in the past Biology in 2015 is heavily dominated by females (1.52:1) and Physics is dominated by males (0.33:1)). Chemistry shows the closest gender balance, with a small excess of females (1.24:1), except in 2014. Ag. Science has a majority of males (0.61:1), reflecting the dominance of men in farming-related careers. Interestingly the figures for mathematics show a small majority of females in 2015, though males are a majority in the HL course.

In Table 9 the grades for all four science subjects are shown for 4 years from 2010 to 2013, at both Higher and Ordinary level.

Table 10 shows the top 10 LC subjects from 2011 to 2015. Maths retains its first place in 2015, if Foundation Maths is included. Nearly everyone who stays on a school until age 17/18 does Mathematics and does an examination in it. Biology is in 4th place and the most popular Science subject. Four subjects are taken by >50% of the LC cohort. Interestingly in the UK Biology, Chemistry and Physics are all now in the top 10 A level subjects and Maths is the top subject.

Table 10: Top 10 LC subjects from 20011 to 2015 (HL+OL)

Subject	2011 Total (HL+OL)	2012 Total (HL+OL)	2013 Total (HL+OL)	2014 Total (HL+OL)	2015 Total (HL+OL)	% LC cohort 2015	Rank 2015
Maths (+FL)	51,991	50,442	50,856	52,382	**53,570**	**97.3**	**1**
English	51,455	50,517	50,817	52,276	**53,123**	**96.5**	**2**
Irish (+FL)	44,397	42,965	43,651	45,268	**46,565**	**84.6**	**3**
Biology	30,349	30,506	31,500	32,956	**33,865**	**61.5**	**4**
French	26,766	25,977	25,517	26,496	**26,798**	**48.7**	**5**
Geography	27.305	25,734	25,295	25,123	**25,131**	**45.6**	**6**
Business	18,083	17,248	16,932	16,515	**16,876**	**30.6**	**7**
History	12,106	11,746	11,822	12,181	**12,183**	**22.1**	**8**
Home Econs.	12,400	11,898	12,048	12,027	**11,897**	**21.6**	**9**
Art	10,782	10,279	10,295	9,833	**9,863**	**17.9**	**10**

Table 11 shows the change in the LC cohort (Established + LCVP) from 2002 to 2015, together with the % of the LC cohort taking Biology, Chemistry, Physics and Agricultural Science (these are shown graphically in Figure 1 above). Biology is clearly in the ascendant and numbers and its % share has climbed steadily since the new syllabus was introduced in 2002 and examined first in 2004. The new Physics and Chemistry syllabi were first examined in 2002 and since then Physics has been on a slow decline and Chemistry on a slow increase, so that Chemistry overtook Physics in 2008 and the gap continues to widen. More students are doing Chemistry now than at any time in the last 10 years. Agricultural Science numbers continue to increase and it has now well overtaken Physics, replacing Physics as the third most popular science subject. If Ag. Science continues to increase at its current rate it may well exceed Chemistry in enrolment in 2-3 years time, however its growth may have stalled. The continuing decline in Physics was a matter of concern, although there has been some recovery since 2012 and it is closing the gap on Ag. Science.

Table 9: 2015-2012 LC Science Results at HL and OL (Current year in bold)

Chemistry	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**NG**
HL 2015	**7,533**	**12.6**	**9.3**	**10.2**	**9.1**	**9.1**	**7.9**	**8.0**	**7.2**	**5.8**	**5.4**	**6.7**	**6.3**	**2.0**	**0.3**
HL 2014	7,226	9.7	10.9	10.6	9.5	9.0	7.8	7.5	7.8	5.9	5.5	6.8	6.0	2.5	0.4
HL 2013	6,756	9.4	11.0	8.2	9.7	9.9	8.4	7.9	8.9	6.3	5.6	6.6	5.7	1.8	0.6
HL 2012	6,705	11.5	8.4	9.9	9.5	9.1	8.2	7.3	8.7	5.3	6.1	7.1	5.9	2.5	0.6
OL 2015	**1,405**	**1.6**	**4.8**	**4.8**	**7.0**	**9.2**	**8.9**	**10.1**	**10.7**	**8.0**	**6.7**	**9.5**	**11.7**	**5.8**	**1.1**
OL 2014	1,378	3.2	6.3	6.0	8.9	9.9	9.4	10.7	8.6	7.5	6.5	7.6	9.1	5.5	1.0
OL 2013	1,399	2.6	4.5	4.2	7.5	9.7	9.2	10.2	10.3	7.6	6.9	9.1	10.3	6.0	1.9
OL 2012	1,381	2.0	5.6	4.9	8.2	9.0	4.0	10.0	9.3	7.9	7.4	8.7	9.9	4.8	1.9
Biology	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C 1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**G**
HL 2015	**25,596**	**6.2**	**8.9**	**9.1**	**10.1**	**10.8**	**9.7**	**9.9**	**9.6**	**7.9**	**6.4**	**6.2**	**4.3**	**0.7**	**0.1**
HL 2014	24,442	5.6	8.0	6.9	8.8	10.1	9.1	9.8	11.1	8.7	7.8	7.4	5.6	1.1	0.1
HL 2013	23,436	5.8	8.6	7.4	9.5	10.4	8.8	9.2	9.9	7.2	7.1	7.8	6.5	1.5	0.2
HL 2012	22,740	7.6	9.1	8.5	9.1	10.1	8.9	9.1	8.7	7.0	6.6	6.9	6.5	1.7	0.2
OL 2015	**8,269**	**0.3**	**1.1**	**2.5**	**6.1**	**10.1**	**12.3**	**14.6**	**14.8**	**11.2**	**10.3**	**8.8**	**6.2**	**1.6**	**0.1**
OL 2014	8,514	0.3	1.3	2.7	5.1	11.0	9.6	13.1	16.5	10.0	10.7	10.5	7.2	1.8	0.1
OL 2013	8,064	0.5	1.6	3.7	6.9	11.0	10.6	11.6	12.6	10.2	8.9	9.0	9.2	3.6	0.6
OL 2012	7,796	0.4	0.9	2.6	5.3	10.0	11.5	14.1	13.6	7.0	8.5	9.0	9.4	3.5	0.6
OL 2011	7,672	0.6	1.6	3.9	6.6	10.1	11.2	13.1	12.2	10.6	8.3	8.7	9.1	3.7	0.4
Physics	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**NG**
HL 2015	**5,764**	**12.2**	**8.4**	**8.1**	**8.9**	**7.9**	**8.0**	**7.7**	**8.0**	**6.7**	**7.2**	**7.4**	**7.2**	**2.0**	**0.3**
HL 2014	5,399	9.8	10.0	8.7	9.3	10.0	8.6	8.0	8.0	6.8	5.9	6.7	6.3	1.5	0.4
HL 2013	4,832	10.1	10.3	9.9	9.8	9.3	8.2	8.1	7.6	7.0	5.8	6.7	5.0	1.8	0.4
HL 2012	4,753	9.7	10.1	10.3	9.7	9.8	8.8	8.4	7.8	6.7	5.4	5.9	5.6	1,3	0.4
OL 2015	**1,744**	**5.5**	**8.9**	**7.1**	**11.1**	**13.0**	**9.6**	**10.8**	**8.0**	**6.9**	**5.0**	**5.3**	**4.9**	**2.9**	**1.0**
OL 2014	1,778	6.1	8.8	7.8	9.6	13.5	8.1	10.0	9.4	5.5	5.1	6.3	6.4	2.7	0.9
OL 2013	1,616	6.0	8.5	7.4	11.6	12.3	8.9	8.0	10.0	4.2	5.8	8.0	5.4	2.8	1.1
OL 2012	1,620	5.3	9.9	8.3	5.0	8.0	8.1	8.6	8.6	4.5	6.4	6.4	6.4	3.2	1.0
OL 2011	1,734	6.0	8.8	6.2	10.6	12.7	6.7	10.3	10.9	4.4	6.2	5.9	7.6	3.2	0.4
OL 2010	1,868	8.0	9.4	9.0	9.8	12.8	7.5	7.2	9.1	3.9	4.4	7.3	5.8	4.2	1.6
Ag. Science	**No.**	**A1**	**A2**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**	**D1**	**D2**	**D3**	**E**	**F**	**NG**
HL 2015	**6,067**	**4.1**	**6.8**	**8.8**	**9.5**	**9.6**	**10.0**	**9.4**	**9.3**	**8.4**	**7.4**	**8.3**	**6.8**	**1.3**	**0.1**
HL 2014	6,329	4.7	6.2	7.2	9.5	9.8	9.4	10.6	9.9	8.8	7.0	8.8	6.8	0.9	0.1
HL 2013	5,951	3.6	6.1	7.6	8.8	10.7	11.3	11.1	10.3	8.7	7.5	7.8	5.6	0.9	0.1
HL 2012	5,587	4.3	5.7	7.2	8.5	10.1	10.3	10.0	9.6	9.3	8.3	8.1	7.6	1.1	0.0
OL 2015	**1,605**	**0.1**	**0.2**	**1.1**	**2.7**	**5.7**	**9.7**	**13.6**	**10.5**	**12.8**	**11.2**	**13.6**	**13.8**	**4.4**	**0.5**
OL 2014	1,597	0.3	0.3	0.8	3.5	5.8	8.4	11.1	12.3	12.3	12,7	14.0	14.3	4.0	0.4
OL 2013	1,463	0.1	0.2	1.2	2.4	4.6	7.7	10.7	13.7	14.4	11.5	15.7	14.1	3.6	0.3
OL 2012	1,302	0.0	0.3	1.0	2.8	5.1	9.1	4.0	6.0	8.0	9.0	1.0	4.0	4.2	0.2

(LC Grading at Higher Level: A1 90-100%; A2 85-89%; B1 80-84%; B2 75-79%; B3 70-74%; C1 65-69%; C2 60-64%; C3 55-59%; D1 50-54%; D2 45-49%; D3 40-44%; E 25-39%; F 10-24%; NG 0-9%)

Table 11: Changes in the LC cohort and science subjects (2002-2015)

	LC Cohort	Biology Total	%	Chemistry Total	%	Physics Total	%	Ag. Science Total	%
2002	58,489	22,064	37.7	6,497	11.1	8,651	14.8	2,890	4.9
2003	56,229	22,669	40.3	6,698	11.9	8,806	15.7	2,972	5.3
2004	55,183	24,027	43.5	7,229	13.1	8,152	14.8	3,237	5.9
2005	54,069	25,362	46.9	7,366	13.6	7,944	14.7	3,625	6.7
2006	50,995	24,885	48.8	7,071	13.9	7,335	14.4	3,912	7.7
2007	50,870	25,792	50.7	6,926	13.6	7,251	14.3	4,267	8.4
2008	52,144	26,607	51.0	7,114	13.6	7,112	13.6	4,738	9.1
2009	54,196	28,160	51.8	7,403	13.7	6,923	12.8	5,272	9.7
2010	54,481	29,249	53.7	7,548	13.85	6,745	12.4	5,787	10.6
2011	54,341	30,349	55.8	7,677	14.1	6,516	12.0	6,473	11.9
2012	52,499	30,563	58.2	8,086	15.4	6,373	12.1	6,889	13.1
2013	52,767	31,500	59.7	8,155	15.45	6,448	12.2	7,414	14.05
2014	54,025	32,956	61.0	8,604	15.9	7,177	13.3	7,926	14.7
2015	**55,045**	**33,865**	**61.5**	**8,938**	**16.2**	**7,508**	**13.6**	**7,672**	**13.9**

*New Biology syllabus examined from 2004 onwards; new Physics and Chemistry syllabi examined from 2002.
LC Cohort is LC (Est) + LCVP

Provision and choice at LC level

A student cannot study Chemistry (or any other subject) in a school if the subject is not provided. There is not equal provision of science subjects in all schools as the Table 12 below shows. If a subject is not offered in a school it may be provided in a nearby school and thus becomes available. When we look at the data it is clear that Biology is offered in virtually every school but both Chemistry and Physics are only offered in some schools, and there are mixed schools where the subject is offered to males only or girls only. One of the results of the austerity measures is that schools have lost teachers and depending on which teachers have retired and not been replaced, subjects may be lost. Surveys by the ASTI of their members have shown that a significant number of schools are considering or have dropped subjects and the physical sciences, with their relatively low uptake, are in the firing line.

Table 12: Provision of science subjects in schools – number of schools 2012-13 school year (% of total) (DoES)

	Single sex schools			**Mixed schools**			
Totals doing LC sciences	**Total (%)**	**Male only**	**Female only**	**Total doing LC sciences**	**Male only**	**Female only**	**Male and female**
Total	***694 (100)***	***110 (100)***	***145 (100)***	***438 (100)***			
Chemistry	557 (80.3)	101 (91.8)	139 (95.9)	317 (72.4)	7	9	301
Physics	524 (75.5)	106 (96.4)	103 (71.0)	315 (71.9)	34	3	278
Biology	686 (98.8)	108 (98.2)	145 (100)	433 (98.9)	1	2	430
Physics + Chemistry	46 (6.6)	5 (4.5)	4 (2.8)	37 (8.5)	2	1	34
Ag. Science	365 (52.6)	55 (50.0)	47 (32.4)	263 (60.0)	16	6	241

There are 255 single sex schools, comprising 110 male only (15.85%) and 145 female only (20.9 %), with 438 mixed schools (63.1%). Ireland has one of the highest percentages of single sex schools in Europe. Provision of Chemistry is highest in single sex schools and lowest in mixed schools, where in a few schools it is only offered to males or females. Physics is offered least in all female schools and in 34 mixed schools is only offered to males. There is a clear gender effect in this case. Biology is almost universally available across all schools. The combined Physics with Chemistry is mainly offered in a few mixed schools. Agricultural Science, the rising star of the sciences, is offered in just over half of schools and is a little more common in mixed schools. Many more schools offer Physics than Agricultural Science (159 more) but more students are now taking Agricultural Science.

There is a long-standing argument about whether single sex schools are better for girls or mixed schools. Table 13 gives science enrolments (over the two LC years) in single sex and mixed schools. Chemistry enrolment in all female schools is greater than that in mixed schools despite there being over twice as many mixed schools. The same is true for Physics and there are three times as many mixed schools offering Physics than all female schools. The same is true to a lesser extent for all male schools – males are more likely to do Chemistry and Physics in these schools than in mixed schools. Table 13 shows how many mixed schools offer science subjects to males or females only. Females are more likely to take Chemistry and Physics in a single-sex school than in a mixed school. 53% of girls taking Chemistry are in 145 single-sex girls schools; the other 47% are in 438 mixed schools. Similarly 54% of girls taking Physics are in single-sex girls schools.

Table 13: Total enrolments in science subjects in the 2012-2013 school year (DoES)
N.B. These figures amalgamate 5th and 6th years.

	Single sex schools (255)			Mixed schools (438)		
	Males only (110)	**Female only (145)**	**Total**	**Males**	**Female**	**Total**
Chemistry	3,276	4,798	8,074	4,367	4,252	8,619
Physics	4,008	1,875	5,883	6,733	1,574	8,307
Biology	10,094	17,689	27,783	16,420	20,854	37,274

Conclusions

The steady expansion of numbers at LC level seems to be starting and in the next few years numbers will increase significantly due to the increased birth rate from 2006 onwards. This will strain resources in schools and at third level in the next decade. From the data it can be seen that Biology continues to be the dominant science, favoured by girls, much more so in Ireland than in other European countries. Chemistry is maintaining its share of the LC cohort and the rise of Ag. Science seems to have halted. All the sciences showed an increase in numbers and % share except for Ag. Science in 2015. A strong feature of Ireland's senior cycle system is that almost everyone does mathematics (>90%) at some level, and the take-up of science is strong. The data is not available to show how many LC students do no science at all, one science or more than one science subject. Physics with Chemistry continues to be the Cinderella science with ~1% of the cohort taking it. The syllabus either needs to be revised and modernised or the subject dropped. Another option would be to create a general science subject, built on junior science, to provide an alternative general course for students who do not want to specialise, and probably for many who presently take Biology as the easy science option.

Although draft syllabuses have been produced by the NCCA in Biology, Chemistry and Physics, and the revision of the Ag. Science syllabus is now under way, it is unlikely that the new science courses will be introduced before 2018. There is still a major question over the practical assessment of the courses and whether this is feasible or not and whether it is affordable or not. Giving any form of practical examination to nearly 50,000 students (amalgamating numbers for Biology, Chemistry and Physics) would be a mammoth logistical exercise and an extremely expensive one. The concerns of the ISTA and others about the new LC science courses, as given in the Hyland Report (2014), have still not been answered and there are major questions about the content and presentation of the new courses.

One important factor, which still needs to be considered, is the integration of the new LC science courses with the revised JCSA science course, due to start in 2016. It is not clear that the new LC science courses have taken into account the revised JCSA course with its reduced hours and less content, and the different teaching approach. There is already a large jump in content and intellectual demand between junior and senior cycle in science, which creates problems for students now, and this may well become worse when the junior science cycle is revised. It is worth restating (see my editorial in this issue), that curriculum development should b done from the bottom up, not from the top down, and every effort should be made to ensure a smooth transition from one level to another.

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REPORTS

9th Chemistry demonstration Workshop:

16-19th June 2015, University of Limerick

"Learning to engage students through demonstrations"

Sarah Hayes

Synthesis and Solid State Pharmaceutical Centre (SSPC) Education and Outreach Officer, University of Limerick

This year more 15 delegates from around the country, including a number of trainee science teachers, attended the 9th annual Chemistry Demonstration Workshop. The workshop has become an annual event in the chemistry/science education calendar and is heading into its 10th year in 2016!

Ice, ice baby! Eimear Nolan, Tarbert Comprehensive School, Laurie Ryan, UL and Sarah Hayes, SSPC; Liquid nitrogen rapidly cooling boiling water and washing-up liquid (Photo: SSPC/Seán Curtain)

Once again, this year the 9th Annual Chemistry Demonstration Workshop was organised jointly by the Synthesis and Solid State Pharmaceutical Centre (SSPC) and the Department of Chemical and Environmental Sciences (CES), University of Limerick, and was supported financially by PharmaChemical Ireland and the Professional Development Service for Teachers (PDST). The workshop aims to develop science demonstration skills and inquiry-based teaching and learning, which will engage and stimulate student's thinking.

The course began on the 15th of June with introductions and lunch, and we then moved into the laboratory with Paul Nugent and David Keenahan from the Institute of Physics (IoP). Paul and David had kindly agreed to visit us before they set off to represent Ireland at Science on Stage in London. Institute of Physics (IOP) to the course and learn all we could from then and their wonderful circuit The Institute of Physics demonstrations have become a regular feature in the Chemistry demonstration workshop and Paul and David always bring fresh new ideas for teaching Physics at Junior and Leaving Certificate. As Paul and David took us through the vast array of Physics demonstrations and their applications we frantically tried and tested them, taking notes about their relevance to the various aspects of the curriculum.

Fionnuala Finlay, Oaklands Community College, Edenderry, Co. Offaly shows us how to 'TWIST' after time with the IoP. (Photo: SSPC/Seán Curtain)

Later that afternoon we had a slightly different coffee break, as the Department of Chemical and Environmental Sciences (CES Department) had a delicious surprise in store: liquid nitrogen ice-cream whipped up by the wonderful Leo Kirby! This is a feature of the opening day of the workshop – edible chemistry! It was the perfect refresher after the heat of the lab! Soon afterwards it was back to Physics!

The following morning it was back into the laboratory to see how a real 'Science Magic Show' operates! The show was presented by Beulah McManus, UL. The University of Limerick delivers a travelling 'Science Magic Show' to schools throughout Munster and continues to do so in the 2015-16 school year (If you are interested email Laurie.Ryan@ul.ie for information).

Once the show was over it was time for the teachers to try it all for themselves. A circuit of demonstrations was set-up around the laboratory and the participants worked in pairs to try all of the demonstrations and build up a portfolio of demonstrations. The circuit consisted of a series of demonstrations that we have developed and used in our courses and Science Shows for years. This offers course participants a unique opportunity to build their confidence slowly and to perfect tried-and-tested demonstrations before making the leap into developing their own. It also meant that all participants started off with a basic set of chemical demonstrations that they could do and take away to use in their schools or in science magic shows.

Chris Kiely, Listowel Presentation Secondary school, Co. Kerry, shows that he has 'Money to burn' (Photo: SSPC/Seán Curtain)

Members of the scientific community and sponsors of the course recognise and advocate the benefits of the workshop: *"Science is all around us and equipping and empowering teachers to bring it to life for students can make the difference in terms of their long-term engagement with the subject. It is important that we continue to nurture students' interest in the sciences to help build our culture of innovation, enquiry and the future knowledge economy."* explains SSPC General Manager, Jon O'Halloran

The course programme is designed to provide science teachers and educators with the confidence to promote problem and inquiry-based learning and to conduct over 40 engaging and interactive science demonstrations, which are linked to real world science applications. After the circuit of demonstrations, teachers were encouraged to try out some demonstrations that they would like to do from the course materials provided in their folder, from the Royal Society of Chemistry Classic Chemistry Demonstrations book or from the internet. Once these demonstrations were assessed for safety and availability of materials, the teachers were good to go and try them out themselves, and this approach allowed for a large number of demonstrations to be tried out and shared among the group.

Jerriann Sullivan knows how to ignite the spark of science! (Photo: SSPC/Seán Curtain)

The guiding principle behind this workshop is to use the first two days to get the participants really comfortable with doing demonstrations (no matter how flaming or explosive they are), and to then allow them to use their new found confidence to research and try out new demonstrations in a safe environment. The goal is to build confidence and expertise based on knowledge and an awareness of safety, and learning from mistakes, as well as learning from others on the course. There is always a session built in to the course offering participants the opportunity to share their demonstrations with the group, which always turns up new and interesting demos!

Event organiser, Sarah Hayes, SSPC Education and Outreach Officer explains: *"This workshop is an important event on the science education calendar. During this workshop we work with teachers and educators to help them enhance their own skills for teaching using inquiry and problem-based learning through utilising spectacular attention grabbing science demonstrations, which have the ability to engage pupils and stimulate thinking."*

Peter Childs, UL, making his great escape from the mentos and coca-cola demonstration!

Peter Jackson from the Professional Development Service for Teachers (PDST) came in on the third day of the course to give a session on using the PDST website and other IT-based chemical resources in the classroom. This session got a very positive response from teachers, both new and experienced alike! This session took place in the Chemistry and Environmental Science (CES) Department IT suite.

Once this session was over, it was back to the grindstone and the teachers continued trying out new demonstrations in the laboratory, and frantically developing and preparing for their own 'Science Magic Show' in pairs.

The participants were allocated to work in pairs, and each pair had the brief to devise, script, practise and finally present their own Science Magic Show at the end of the workshop to the other teachers (and invited guests). These shows were videoed so that teachers could learn from theirs and other's performances after the workshop was over. These videos are only circulated to participants and sponsors – they are not for public consumption! Peter Childs said *"Teachers need the opportunity to step back from teaching and to develop new skills and new ways of presenting science. These workshops give them the time to build their confidence and expertise, to share ideas with fellow teachers, and we find that they return to their schools invigorated and more enthused about teaching chemistry."*

The workshop is subsidised by the sponsors, so that teachers only pay part of the cost, which includes meals and full board for 4 days, as well as tuition and course materials. This makes it very good value for money and a great opportunity to meet other teachers and work together in a collaborative venture to improve one's chemistry demonstration skills. The feedback from teachers and students over the years has been very positive and attending the workshop can revitalise one's teaching and give one a new a new enthusiasm for practical science.

Chris Kiely helps light Rebecca Kearney's and Laurie Ryan's fire! (Photo: SSPC/Seán Curtain)

The workshop has been enhanced and developed upon the foundations of Student Active Learning in Science (SALiS, www.salislab.org), an international project, which utilises best-practice within science education, funded by EU-TEMPUS. On-going research in this area is continuing through the EU FP7 funded project TEMI (contact: peter.childs@ul.ie or sarah.hayes@ul.ie). For further information about SSPC or the workshop contact Sarah Hayes, SSPC Education and Outreach Officer email: sarah.hayes@ul.ie.

The programme is designed to help teachers put fun back into teaching and learning science in school and allow participants develop confidence in developing spectacular but safe chemical demonstrations.

This workshop is residential and most of the costs are covered by the sponsors – the SSPC, the CES Department, the Professional Development Service for Teachers (PDST), and Pharmachemical Ireland (through Siobhan Dean). The workshop was also supported by the course organisers and presenters were Sarah Hayes (SSPC), Peter Davern (CES/SSPC), Beulah McManus (CES) and of course, Peter Childs (CES).

Nearly 100 teachers and student teachers have attended the eight workshops. We frequently give scholarships to final year science education students from UL and other teacher education universities around Ireland, who are training science teachers. We hope to run a 10th Chemistry Demonstration Workshop in June 2016, and this will be even better than ever before for the big 10th anniversary!. The courses cost €150 for 4 days full board. Places are limited (~20) - so if you are interested please e-mail either Sarah Hayes (sarah.hayes@ul.ie) or Laurie Ryan (Laurie.ryan@ul.ie) to reserve a place in 2016.

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STOP PRESS

New Education Coordinator started

I am delighted to announce that our Education Coordinator in Trinity College is now in post. I am sure that you will join me in welcoming Dr John O'Donoghue to our regional chemical sciences community.
A UCC graduate with strong science outreach experience, John will work closely with Dr Stephanie Nelson to support teachers, students and local advocates to develop the next generation of Chemists! John will be making plans to meet you all in the coming weeks.

Education Awards 2016

Our Education awards portfolio has been updated and nominations are open from 1st October until January 15th 2016.

- **Education Awards Portfolio.**
  This is designed to reach **HE lecturers, HE technicians and chemical education researchers**. Peers can nominate each other and also undergraduates could also nominate their favourite lecturer.

- **Schools Education Award**.
  This is aimed at teachers, heads of department, governors, parents and school leaders – i.e. **anyone who may wish to recognise an inspirational chemistry teacher or a team of educators in a school** (e.g. chemistry department). The criteria have changed significantly for 2015/16 to better reflect what teachers value. The winner(s) now receives a medal and £2000; the science department receives £1000. You no longer have to be a member to nominate someone for this award.

Please feel free to contact me if you need more information on any of the above and I look forward to speaking with you all in the near future.

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